Jac. Berzelius and the emerging modern chemistry

By SIGVARD STRANDH

Every year since 1956 the Swedish Society of chemists in cooperation with the Tekniska Museet has arranged "Berzelius's Memorial Lectures" to which every time about hundred young people from schools and colleges in all parts of the country are invited to hear lectures on chemical problems of current interest. On January 2, 1970, Mr. Sigvard Strandh, Director of the Museum, presented his youthful audience the following picture of the famous Swedish chemist after whom the Lectures have got their name.

Youth — in the tradition of Linnaeus

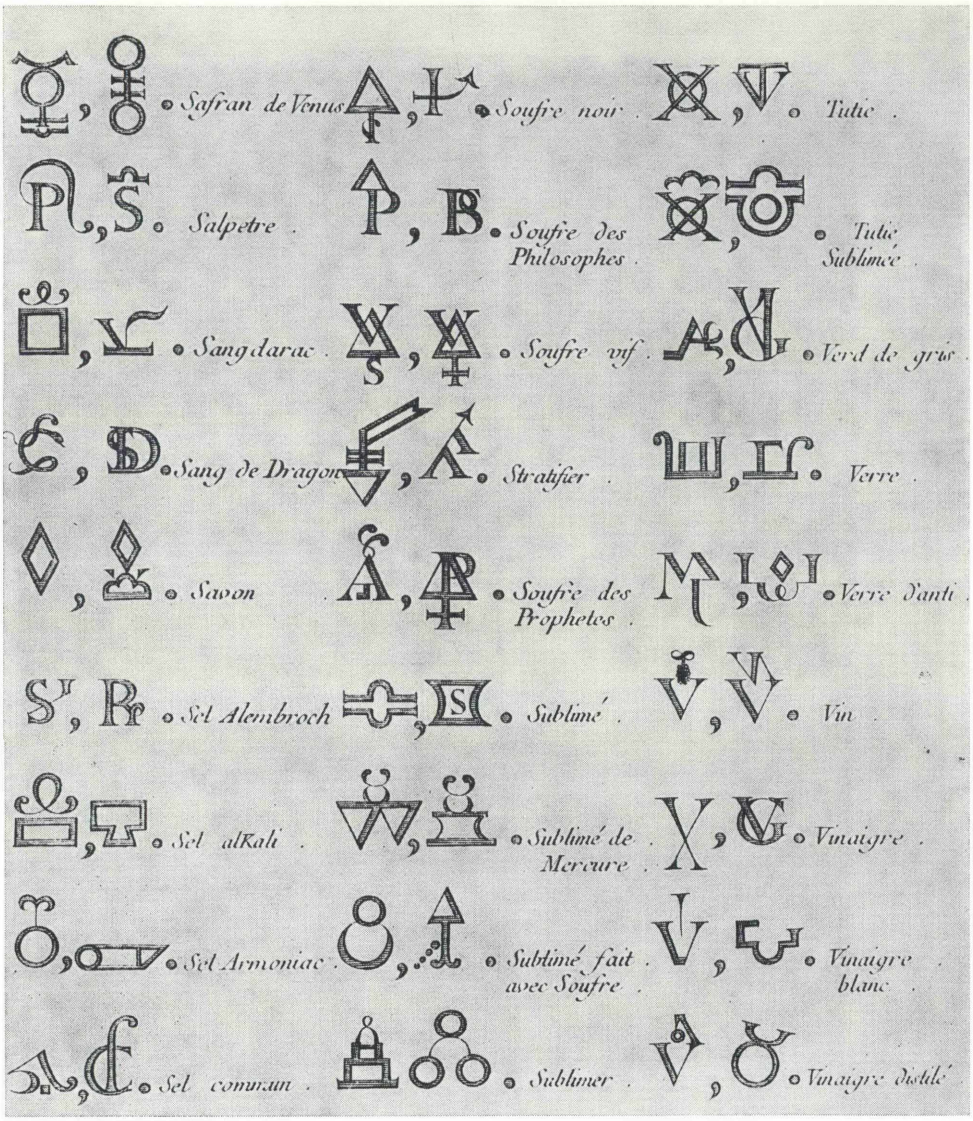
Jöns Jacob Berzelius was born in 1779, a year after the death of Linnaeus, the great Swedish botanist, and his life was destined to be associated with Linnaeus in many other ways than merely by virtue of this succession in years.

By the time Jacob Berzelius reached the end of his life in 1848 tokens of honour had been bestowed upon him by academies and learned societies from all over the world. Even during the course of his career his achievements had been compared with those of the celebrated Linnaeus and when the monument of Berzelius was unveiled in the Stockholm park, which now is named after him, the customary poem of homage included the following stanzas:

Hidden forces of the Nature
stones, water, plants and beasts,
all you brought into good order,
studied, weighed and well defined
— — — — —
Learn us find the ways of Nature,
seek the soul of slag and grass,
feeling grief at having lost you,
ever proud of Linné and you.

Berzelius like Linnaeus was the son of a clergyman, his grandfather and his great grandfather were also clergymen. He was born in the parish Väversunda in Östergötland, on the shore of the lake Tåkern, the famous breedingplace of thousands of aquatic birds. He grew up in close contact with nature, revealing a keen observing mind and an explorer's delight at his discoveries, qualities which he shared with Linnaeus.

Berzelius attended the Linköping grammar school, and the intention was that he should follow his father's calling. At that time the grammar schools were designed specifically to prepare their pupils for the law and the church. But instead of devoting himself to ecclesiastical history and classical languages Jöns Jacob preferred to stroll about in the beautiful surroundings of Linköping, often neglecting morning prayers for the sake of these excursions. By good fortune the teacher in natural history at Linköping grammar school was the Linnaean Claes Fredrik Hornstedt, who in his younger days had travelled widely collecting plants, birds and insects from such remote places as the East Indies and South Africa.



Chemical symbols, circa 1760. From Diderot Encyclopedia.

Hornstedt took the energetic young scholar under his wings and initiated him in Linnaean systematics. He likewise instructed Berzelius in the art of assembling and preparing a proper natural-history collection, which quickly expanded to embrace some 400 species, chiefly insects but also various birds and animals brought down during shooting expeditions across the country-side. It was this latter pastime, hardly in keeping, perhaps, with the pursuits of the true naturalist, which almost terminated Berzelius's school career prematurely; the statutes of the clerical grammar school strictly forbade its scholars to possess or make use of any form of firearm. Neither for that matter was Berzelius's manifest interest in natural history, a newfangled and dubious science at that time, approved of by his academic mentors. Consequently Berzelius was threatened with expulsion and it was only through the timely intervention of Hornstedt that he was delivered from this.

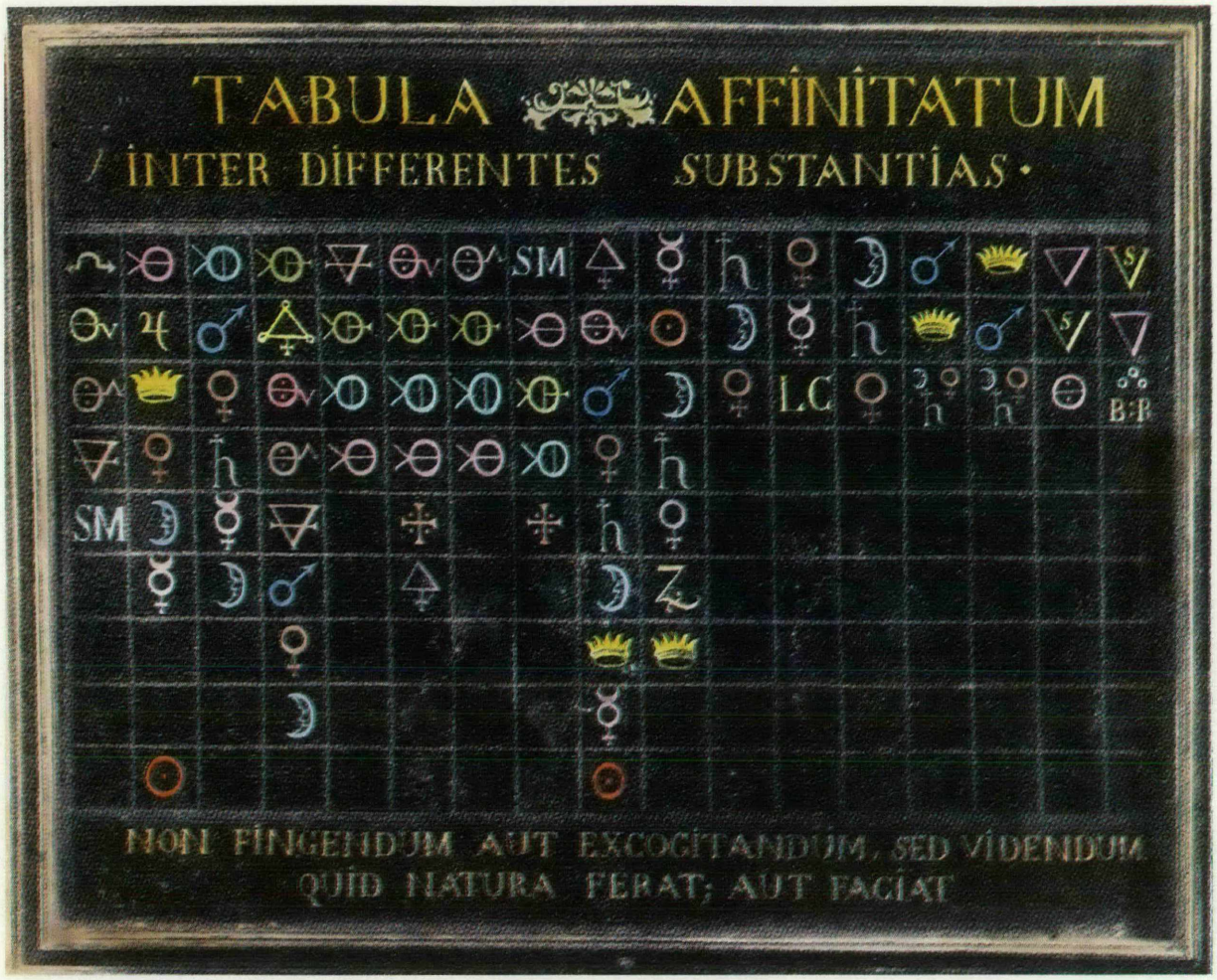
Thus the Linnaean Hornstedt had a decisive influence on Jöns Jacob Berzelius's schooling and progress in the field of natural science. He infused the young scholar with an enthusiasm for scientific research which was to remain with him all his life and inspired him to penetrate the mysteries of nature and seek its hidden secrets.

Berzelius became so engrossed in his natural science studies that when he sat for the matriculation examinations in 1796 he was one but last on the results list and in his leaving certificate he was described as "a youngster with plenty of natural ability, unsatisfactory habits and doubtful prospects". In his notes Berzelius refers to these comments with understandable indignation, but at the same time he gratefully quotes the appreciating words of the Bishop of Linköping uttered when handing him his leaving certificate. "You have neglected many hours of study, but I am aware that you have not wasted this time. Continue to devote yourself to the realm of knowledge which you prefer and your endeavours will not go unrewarded." There is no doubt that Berzelius in his sad state of mind took the Bishop's words to his heart. The kind words were not only just, they were also prophetic.

At the same time, however, the comments on the leaving certificate reflected inherent characteristics in Berzelius's nature which he was to retain throughout his life, the slightly jocund playfulness of a schoolboy, a trace of roguishness possibly. An agreeable vein of facetiousness permeates much of his scientific work.



Berzelius at the age of 47. Portrait by John Way, 1826. The Library of the Royal Swedish Academy of Sciences



Chemical symbols, used by the Swedish chemist Torbern Bergman (1735—84) in his table of chemical affinities, circa 1775

In Uppsala — on the threshold of a scientific career

The presentiments of the cleric on the talents of the young Berzelius were soon to be confirmed when in the autumn of 1796 he entered the University of Uppsala. On the recommendation of Hornstedt, who was a M.D., he took up medicine, a science which was so closely allied to the dissection of animals and the quest for medicinal herbs. In those days the study of medicine began with comprehensive courses in physics and chemistry, and here Uppsala had upheld a brilliant record ever since the golden era of Linnaeus. Carl Wilhelm Scheele, Torbern Bergman, Johan Gottlieb Gahn and Johan Gadolin were among the great men who had either taught at, or attended Uppsala during the decades prior to Berzelius's arrival there. And it was in the borderland between physics and chemistry that Berzelius now found the subject of his *pro gradu medico* thesis. In 1799 Alessandro Volta had presented the construction of his famous electric pile and his observations on the effects of the galvanic current. Berzelius made his own pile and proceeded to conduct a series of brilliant experiments on the physical and chemical effects of the galvanic current. This work gave rise first to a plainly written paper entitled "A Treatise on Galvanism", published in the spring of 1802. In May the same year he presented his doctor's thesis where he reported on his experiments in the medical use of galvanic current for curing all kinds of complaints from swollen knees to St. Vitus's dance. In his list of treated cases Berzelius was able to cite only one positive result: a certain improvement in the locomotive faculty of a man suffering from numb fingers, but the thesis, a mere fourteen pages, was nevertheless a pioneer work in a new field of medical science. It might even be described perhaps as a first instance of what we now call medical technology, that branch of medical science with its vast range of electrical and electronic aids and methods which we have at our disposal today.

The discovery of cerium — emergence as a chemist

Berzelius had secured his doctor's degree, and secured it with honours, at the tender age of 23 and now, having left Uppsala for Stockholm, entered enthusiastically into the medical, physical and chemical debates of the day. He made a living as a county medical officer on the islands of Lake Mälar, but at the same time cultivating his acquaintances among the patrons and men of sciences of the capital. Berzelius found a friend and fellow researcher in the talented young foundry proprietor Wilhelm Hisinger and together with

him continued his studies in the use of galvanic current in chemical analysis, a pioneer work which aroused international attention. Hisinger made available to Berzelius an apartment and an adjoining laboratory. In 1803 Berzelius and Hisinger, independent of each other, succeeded in isolating a new element which they named *cerium* after the recently-discovered asteroid Ceres. Then as now the discovery of a new element was a major achievement in chemistry and a number of prominent scientists both in Sweden and abroad tried to deprive the beginner of the priority. Among others the renowned Martin Heinrich Klaproth asserted that he had himself made the same discovery in an analysis of the mineral which Berzelius and Hisinger had used; Bastnäs-tungsten from the Riddarhyttan in the province of Västmanland. The discovery of cerium aroused a scientific excitement, the like of which, says Söderbaum, Berzelius's biographer, had not been witnessed since C. W. Scheele disputed on phlogiston and oxygen with Europe's leading chemists in the 1770's.

This must have been a very trying period of the young Berzelius who just then was faced with serious economic problems. At this time, 1805, he earned his bread as a physician to the poor in Stockholm; his income was extremely modest and he was burdened with heavy loan commitments. However, following the discovery of cerium it must have become evident to him that chemistry was his true calling and he applied for the professor's chair in chemistry which had become vacant through the death of the Linnaean disciple Anders Sparrman. Despite Berzelius's indisputable qualifications for the post and even though he had served for two years as Sparrman's locum tenens, the professorship went to the twelve year senior Doctor of Medicine Conrad Quensel who had extensive experience in the Linnaean fields of natural history, pharmacology and medicine.

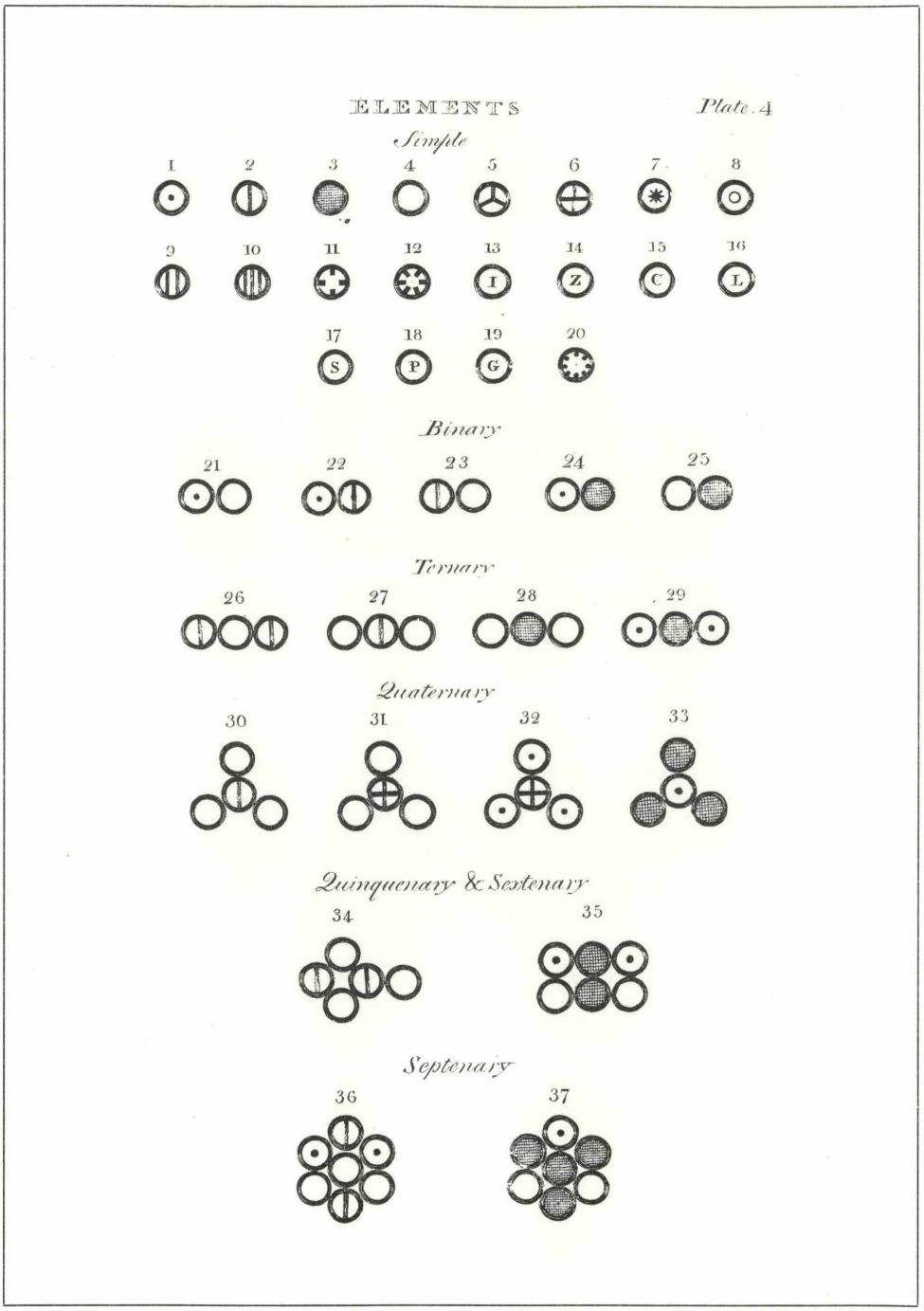
This was a hard blow to Berzelius and it very nearly altered the entire pattern of his career. But once more fate intervened and less than a year after his appointment the new Professor of Chemistry followed his predecessor into the grave. There was no question now about the next appointee and in 1807 Jacob Berzelius was made Professor of Chemistry, finally enabled to devote all his time to his cherished science. His biographer observes here that this chance occurrence redeemed Berzelius for chemistry and that the abrupt demise of his predecessor was of decisive importance to the development and history of chemistry.

The Professor — researcher, pioneer

Once he was appointed, Professor Jac. Berzelius — as he now wrote himself — moved to another laboratory. The kitchen at the old Royal Bakery had been converted into an instructional laboratory for the *Collegium Medicum* which was in those days housed in Kungshuset at Riddarholmen, once the abode of the royal family. The laboratory was not particularly well fitted out, there was neither furnace nor smoke-flue and instead the open hearth, which otherwise in those days was essential in a chemistry laboratory, filled the air with suffocating smoke and fumes of the various experiments. This was before the fume cupboard had been introduced and consequently all the windows and doors had to be kept open for the purpose of ventilation. These were primitive conditions, and Berzelius mentions in his notes that during the severe winter of 1813—14 the temperature in the laboratory was often as low as minus 8—12° "according to the Swedish thermometer", e.g. Celsius' centrigrade scale. But despite the shortcomings he set about his work with an enthusiasm which was soon to produce several important results. When he began preparing his lectures for medical students Berzelius quickly realized that the foreign textbooks in physiological chemistry were very inadequate and the information they offered simply misleading. Thus aided by his assistants he embarked on a systematic analysis of animal matter, which thanks to the efficiency of his more and more refined methods resulted in a detailed presentation of the chemical constituents of bone, meat, blood, gall, urine and many other substances. He found that the colouring agent in blood contained iron in stable bonding and also discovered lactic acid in the musculature. This acid had already been described by Scheele in 1780 who had found it in sour milk. Berzelius presented his findings in animal chemistry in the large work, "Lectures in animal chemistry", 1808, and likewise in numerous individual papers. One of the latter which aroused widespread interest internationally dealt with the analysis of the fluids and tissues of the body.

The master of "the art of noble cooking"

As time went by Berzelius became increasingly interested in inorganic chemistry, particularly minerals and the qualities and compounds of the newly-discovered metals. At the Berzelii Monday Club, the salon over which he presided regularly and which was attended by his colleagues and the learned men of Stockholm, Berzelius referred to this branch of chemistry as "the art of noble cooking". At this society



Chemical symbols and rel. weights according to Dalton. (After Dalton, New System of Chemistry, 2nd ed, Manchester, 1842)

PLATE IV. This plate contains the arbitrary marks or signs chosen to represent the several chemical elements or ultimate particles.

Fig.			Fig.		
1	Hydrog. its rel. weight	1	11	Strontites	46
2	Azote	5	12	Barytes	68
3	Carbone or charcoal	5	13	Iron	38
4	Oxygen	7	14	Zinc	56
5	Phosphorus	9	15	Copper	56
6	Sulphur	13	16	Lead	95
7	Magnesia	20	17	Silver	100
8	Lime	23	18	Platina	100
9	Soda	28	19	Gold	140
10	Potash	42	20	Mercury	167

21	An atom of water or steam, composed of 1 of oxygen and 1 of hydrogen, retained in physical contact by a strong affinity, and supposed to be surrounded by a common atmosphere of heat; its relative weight =	8
22	An atom of ammonia, composed, of 1 of azote and 1 of hydrogen	6
23	An atom of nitrous gas, composed of 1 of azote and 1 of oxygen	12
24	An atom of olefiant gas, composed of 1 of carbone and 1 of hydrogen	6
25	An atom of carbonic oxide composed of 1 of carbone and 1 oxygen	12
26	An atom of nitrous oxide, 2 azote + 1 oxygen	17
27	An atom of nitric acid, 1 azote + 2 oxygen	19
28	An atom of carbonic acid, 1 carbone + 2 oxygen	19
29	An atom of carburretted hydrogen, 1 carbone + 2 hydrogen	7
30	An atom of oxynitric acid, 1 azote + 3 oxygen	26
31	An atom of sulphuric acid, 1 sulphur + 3 oxygen	34
32	An atom of sulphuretted hydrogen, 1 sulphur + 3 hydrogen	16
33	An atom of alcohol, 3 carbone, + 1 hydrogen	16
34	An atom of nitrous acid, 1 nitric acid + 1 nitrous gas	31
35	An atom of acetous acid, 2 carbone + 2 water	26
36	An atom of nitrate of ammonia, 1 nitric acid + 1 ammonia + 1 water	33
37	An atom of sugar, 1 alcohol + 1 carbonic acid	35

he emphatically declared in 1810 that he had now penned the last of his "gall, snot and urine papers". Despite this disparaging remark on organic chemistry, he nevertheless returned to it from time to time, especially during the latter part of his life when he became the discoverer of several new organic acids.

Berzelius's eagerness to apply his analysis techniques to inorganic chemistry was prompted by the same circumstances that had influenced him in his physiological chemistry a few years earlier, namely the inadequacy of the existing textbooks. He had decided to write his own textbook in chemistry and it was now he realized that not even the most common chemical elements and compounds were properly described in the current literature. On the contrary these publications were a veritable jungle of apocryphal and contradictory terms and descriptions. Not even such simple compounds as water, carbon dioxide and ammonia were correctly classified as to their components. This offended Berzelius's sense of systematics and his craving for accuracy. He at once plunged into the immense task of making order out of chaos, commenting: "This idea remained the background of my scientific endeavours during the greater part of my working years; my work on chemical proportions."

In his qualitative analysis Berzelius transformed blowpipe analysis into a masterly technique. The use of the blowpipe, with reagents, for chemical analysis had been introduced by the metallurgist Axel Fredrik Cronstedt (who discovered nickel in 1754) and was further developed by the mining specialist Johan Gottlieb Gahn in Falun. Berzelius often called on Gahn to collect minerals, and it was here that he learned to use the blowpipe. Subsequently this simple device became of major importance in his analytical work in connection with the publication of a textbook on chemistry. Part I of Berzelius's celebrated "Textbook on Chemistry" appeared in 1808 and was in reality a concise compendium. It was subsequently enlarged and published in several editions. Part II came out in 1812, to be followed by further volumes at intervals of a few years until the final volume, Part VI of this great pioneering work, appeared in 1830. Like his previous textbook "Lectures in animal chemistry", these six volumes, for a long time the chemist's standard work, were published in several languages and numerous editions.

In Part II of the Textbook on Chemistry, Berzelius had, together

with Gahn, included a very authoritative and widely used chapter on blowpipe techniques. In due course he expanded this into a separate publication entitled "The use of the blowpipe in chemistry and mineralogy" (1820). The blowpipe had rapidly become what might be described as the "Chemist's stethoscope" and within a few years this latter publication, too, had been translated into many European languages.

In order to be able to determine the combining weights of the elements Berzelius had to refine his quantitative analysis methods. And here, too, Gahn was the forerunner. Lavoisier (1743—94) is said to have been the first man to have used scales as an instrument for chemical experiments, and Gahn (1745—1818) was probably the first person in Sweden to make use of this technique. Gahn had designed an interesting set of analysis scales (now in the Tekniska Museet, Stockholm) and Berzelius describes this device in detail in his textbook, along with explicit procedure directives for accurate weighing.

In his untiring efforts to determine combining weights through quantitative analysis Berzelius was extremely exacting in terms of precision and purity. Here again the Linnaean approach is prominent: the keen sense of observation, the boundless satisfaction in establishing the order and system of matter. As early as 1818 Berzelius was able to produce impressive results from his analyses: atomic weights of 45 of the 49 known elements. Later he presented analyses and descriptions of more than 2000 compounds.

Berzelius achieved the greater part of this work by himself; this careful master of analysis was not prepared to leave such work to his assistants. His contributions were all the more remarkable insomuch that he had to devise his own methods and techniques. His unremitting efforts with blowpipe and analysis scales and with all the concoctions which he prepared in "the art of noble cooking" gave him an unprecedented grasp of chemistry in its entirety.

The symbols of chemistry — the history of chemistry in a nutshell

Prior to Berzelius's work general ignorance and lack of order prevailed respecting chemical elements, compounds and processes and, what is more, a great deal of superstition relating to chemical symbols and terminology. Even as late as at the beginning of the nineteenth century the terminology and symbols of chemistry presented elements inherited from ancient mythological ideas of a relationship between the celestial bodies and the seven known metals. The word chemistry

itself is said to derive from Khemi'a, the Greek form of a native name for Egypt, Cham (Chym, Chem), e.g. the land of black earth. Chema would then be interpreted to mean Egyptian arts, probably with the implication of black magic, and would relate first and foremost to the making of precious metals. Those who conducted this art surrounded their activities with an aura of mystery. The interest of metals was cultivated by the learned men of that time as a secondary to the primary science of astronomy which was then flourishing in the countries around the Nile.

The sacred number seven related to symbols that united the celestial bodies with the earth's metals. There were seven known planets (these included the moon and the sun), there were seven basic tones in the music scale, seven main colours in the rainbow and there were seven known metals. The symbols for the planets were adopted for the metals — or vice versa perhaps — and in graphic metaphors the wise men of the times sought to present common factors among the qualities of the metals and the planets.

The most precious of all metals, gold, which was found to be unaffected by acids or corrosives, was associated with the sun god and was thus given the solar symbol: the circle, also the symbol of perfection. The metal's differing degrees of resistance to the four elements, earth, air, fire, water, were expressed by the cross, the symbol of decay, worked into the symbol of the metal in such a way that the configuration indicated the element that attacked the metal most.

The study of corrosion which is such a vital factor today, is evidently a very ancient facet of chemistry. The antique symbols in relation to the durability of metals, however, were not entirely logical, partly because the cross was also used in connection with the changes and phases of the planets.

The silvery crescent moon was adopted for the "semi-precious" metal, silver. Copper had something of the brilliance of gold — the circle — but was not resistant to water and earth so that the circle was accompanied by an inverted cross below it. The same symbol was used for the planet Venus. Iron was regarded as more durable, but it was affected by air and water to an extent which justified half a cross. This half cross became an arrow pointing at an angle between the realms of fire and water. The Hindus of ancient India as well as the early Egyptian astrologers used a symbol of Mars which was

strikingly like that of iron. In the mythology of the medieval countries the planet Mars was identified with the god of war and strength, and iron — the strong metal — was given the Mars symbol, the Romans' signum martis.

Difficulties arise in interpreting the symbol for mercury, if one attempts to apply the configuration of the basic components in relation to earth, air, fire and water. The components can be seen as the symbols of silver and gold in association with earth and water. In alchemy these components can have illustrated the role of mercury in the making of gold and silver. The basal cross would then refer to the minerals which were used in the refining of these metals. The use of the mercury symbol for the planet Mercury as well, also suggests this connection with the precious metals.

This system of symbols, originally simple, was elaborated by the Greeks and Arabs. The demand for metals increased, and not only for precious metals but likewise for metals for practically useful articles. New methods were studied for making and processing such metals and the question of colouring them arose. It was felt that it should be possible to colour metals in the same way as textiles were coloured and impregnating agents were thus sought. It emerged that calamine (zinc carbonate) would be used to turn copper yellow, the product was brass. A fourth century papyrus found at Thebes contained a collection of formulae for such metal colouration. In fact this was merely a study of alloys and the combining of metals with other substances, phenomena which at that time were not fully understood. Mystical explanations were produced for these colour changes, resulting in the conviction that the actual qualities of metals could be changed so that by degrees one metal could be turned into another. The idea of turning a non-precious metal into silver or gold was a fascinating one and gave rise to the fateful delusions of the alchemists (alchemy — *chemia* prefixed by the Arabis article *al*).

One can well imagine the visions this must have created among men of power and influence during the early Middle Ages; the making of gold was, after all, the key to power and glory. And this preoccupation with the transformation of metals was to hold the science of matter in an almost hypnotic grip for a thousand years or more. The grand master of the alchemists was the mythical Egyptian Hermes Trismegistos, "the thrice-greatest Hermes", who was supposed to have lived in the fourth century and produced innumerable manuscripts

on the making of gold. During his expedition through Egypt in the thirteenth century Alexander the Great had the pretended grave of Hermes unsealed and found there a mysterious inscription on a tablet of precious stones. Ambitious interpretations of this "tabula smaragdina" became a popular subject of dissertations in the sixteenth and seventeenth centuries and from the myths that arose relating to Hermes' alleged doctrines on the making of gold there developed the term "the Hermetic art"; the science of alchemy known exclusively to the chosen few. The metal symbols, augmented with a variety of weird symbols for other subjects, became the secret language of the alchemists. Bewitched by the absolute conviction that they could discover the "philosopher's stone" whereby anything could be transformed into gold and all ailments cured, the alchemists used every means possible to prevent the spread of their knowledge. Many of these alchemists and especially the renowned physicians of the time had considerable practical knowledge in chemistry and metallurgy.

The first attempts to break down the edifice of the alchemists' speculative ideas were made at the close of the seventeenth century when the ideas of Robert Boyle (1626—91) began to gain ground. In his paper "Chymista scepticus" (1661) Boyle presented a new and revolutionary way of thinking. Terms such as element and chemical compound were defined in terms which have been accepted ever since. Boyle also introduced a new concept of *the experiment* as a basis for the observation of chemical phenomena; the empirical inductive method, which was a direct contrast to the alchemists' approach of seeking interpretations to substantiate already established dogmas.

It took a long time, however, before Boyle's ideas were able to overcome effectively the bastions of "the Hermetic art". Princes and those in power were still obsessed by the firm conviction that boundless riches could be acquired through the skills of their alchemists. In Sweden even Gustavus III secretly became a patron of various goldmakers probably in the vain hope that one of these might help him to rescue the public finances. At the time of this royal interest in alchemy the eminent Swedish chemist Torbern Bergman devoted his interest to the old chemical symbols. Along with H. T. Scheffer he improved the ancient symbols and elaborated them with geometrical figures to form a sort of stenographic script for describing elements as well as compounds. In a paper published in 1774 Bergman and

Scheffer described no less than 144 such symbols, enthusiastically pointing out the advantages of this method of notation. Bergman's often very complicated symbols were in themselves quite logically constructed, especially in illustrating the affinity between the different elements and compounds. For Bergman this symbol script became the tool of his theories on chemical affinity which even today can be described as the foundation of qualitative analysis.

At the beginning of the nineteenth century new ideas were developed which prepared the way for the emergence of chemistry as an exact science. An important contribution to this was made by John Dalton (1766—1844), the founder of modern atomic theory. Dalton revived the idea of Democritos that matter is composed of indivisable units, i.e. atoms. In a paper from 1808 Dalton presented a new chemical sign language based solely on this atomic theory and consisting of circels containing figures and symbols. Moreover, by making a symbol represent a certain *quantity* of the substance in question — the atomic weight, Dalton took the first steps towards creating a chemical formula system. The atomic theory and the law of multiple proportions arising from this theory could both be intelligibly presented through Dalton's system of symbols, which quite certainly facilitated the rapid spread af these axioms of modern chemistry.

Berzelius's pioneering contributions

At this time, around 1810, Berzelius was deeply engaged in his pioneering work on the analysis and description of chemical compounds. Through his very exact determinations of the quantities we now call atomic weights Berzelius was able to verify the theories of Dalton. In his autobiographical notes Berzelius gives an expressive description of the situation. "Through new experiments I quickly realized that Dalton's values were lacking in that accuracy which was necessary for the practical application of his theory . . . I saw that if this new constellation was going to spread its light over the entire science, then to begin with the atomic weights of as many of the elements as possible must be determined with a maximum of accuracy. Also the proportions had to be determined according to which compound atoms combine with each other. Without such a work no day would succeed this dawn".

Berzelius was one of the first to accept John Dalton's atomic theory, and he recognized immediately the fundamental importance of this theory to the solution of the central problems of chemistry at

that time. Berzelius's prime interest was in determining "the chemical proportions", the basis of what later became the stoichiometrical law of compound weights. As early as in the 1790's the German Benjamin Richter and the Frenchman J. L. Proust had expounded the theory that elements combine according to specific weight proportions, i. e. "that Nature always creates new substances with a pair of scales in her hand". These ideas made a deep impression on Berzelius and he directed his immense quantitative analysis work at developing these ideas into an established theory. With the advent of the stoichiometric laws, based on the atomic theory, chemistry became a science in the modern sense of the term.

Berzelius was at the very centre of this revolution in scientific reasoning — "the dawn of a new day" — and he now set about eliminating the last remnants of medieval black magic from chemical symbols and terms. With the new ideas which he so skilfully synthesized Berzelius had created the tools that were needed to clean out the undergrowth of erroneous and misleading descriptions of chemical substances which he had encountered when he began work on his own textbooks. Through the medium of the papers he wrote Berzelius endeavoured to establish a universal nomenclature. The maze of ambiguous and unmanageable names for elements and compounds which chemical literature had to put up with at that time was unquestionably a serious impediment to lucid scientific reasoning and the fancyful chemical symbols were a similar obstacle. Torbern Bergman commented on this: "Formerly science was enveloped in obscurities. The most abstruse terms and the most absurd signs were used to represent things which, it was felt, ought not to become common knowledge. And more often than not they probably had in view to conceal ignorance with the signs of eminent learning".

In a paper entitled "Essai sur la nomenclature chimique", published in 1811, Berzelius presented proposals for a chemical nomenclature with Latin names according to a carefully considered system. In his introduction to the Swedish version of this, published in the Papers of the Academy of Sciences, he wrote:

> The sciences are to the benefit of mankind only to the extent that their results keep to the point and are expressed in terms which can be generally understood. But the learned as well, even though they might use their special languages, in every science require certain general expressions which can be used as scientific terms in different languages, and no common language is better suited for this

than Latin. Without such a general nomenclature all terms quickly become indeterminate, unspecific and differently used by various authors. Consider natural history before the time of Linnaeus: what difficulty there was in understanding the author, what a remarkable number of synonyms there were for every plant and every animal, confusing everything and making science difficult to understand. But now, when we use the general nomenclature of Linnaeus with its self-explanatory names, the authors can better be understood and the reader is not deterred by the names of different objects in natural history, which names may not be traceable in the dictionary.

Berzelius's work on qualitative and quantitative analysis, combined with his pronounced sense of systematics meant that he was exceptionally suited to the task of bringing order into the science of chemistry. His most important contribution was his extirpation of still existing shoots of the classical symbolic language of chemistry. In a paper in 1814 he developed his ideas of a universally applicable chemical formula system, "just as practical as the algebraic formulae of mechanics," and observed:

The chemical signs have to be letters so that they can by written and printed easily. I thus propose the initial letter in the Latin name for each element. The chemical sign always expresses a volume of the substance in question. Several volumes are given by adding the numbers of the volumes. (In this quotation "volumes" mean "atoms".)

Berzelius was greatly in favour of Dalton's atomic symbols, but felt that the learning by heart of the many figures was an unnecessary burden. He also pointed out the obvious impracticability attached to printing the signs. The idea of using letters had been put forward earlier but the essential aspect of Berzelius's system was that he got rid of all the peculiar figures and went the whole way to an analogy with the formulae of mathematics.

Berzelius's chemical signs won rapid recognition internationally, except in England where to begin with they were received with some reservation. The emergence of a chemical formula system was without doubt one of the most significant milestones in the history of chemistry and it facilitated immensely the exchange of ideas among scientists.

Aspects of Berzelius's later activities

Berzelius was scarcely forty years old when in 1818 he published the results of his extensive analysic labour in the fifth part of a work, entitled "Treatises in Physics, Chemistry and Mineralogy". This was a monumental work, the culmination of more than a decade of

persistent laboratory studies. In this work he made use of his new nomenclature and formulae. During these ten years or more Berzelius had worked immoderately hard, so much so that he had a breakdown and was advised to take an extended tour abroad. He left for Paris via London and spent more than a year among the great chemists of France, Gay-Lussac, Dulong, Biot, Berthollet and others.

During his absence he was appointed secretary to the Royal Academy of Sciences. The advantages associated with this well-salaried post included the use of both a laboratory and a residence on the Academy premises.

One of Berzelius's undertakings as secretary to the Academy was to present an annual report on research findings and to summarize the scientific debates in the realms of chemistry, physics and mineralogy. The first of these reports appeared in 1821, and Berzelius continued to present them regularly each year until his death in 1848. These were brilliant surveys of the advances in the sciences at that time. They were translated into German, for a succession of years by Berzelius's apprentice Friedrich Wöhler, and were widely circulated among the chemists of the world. In this way the Royal Swedish Academy of Sciences and its secretary attracted the attention of the whole scientific world, especially since Berzelius would often furnish his reports on the treatises of other scientists with his temperamental comments. For many of Europe's great chemists these annual reports were an eagerly awaited but also dreaded reading, of some authors in chemistry received with feelings, not unlike those of actors watching for the reactions of the critics after a first night.

Berzelius's reports also included his own theories and findings. Thus in 1835 he presented the results of his studies in catalysis, including a detailed discussion on the chemical as well as the biological aspects of this phenomenon. Concerning this first, in the history of learning very remarkable, presentation of the term catalysis, Erik Jorpes writes in his biography of Berzelius:

> The introduction is an unparalleled document which every chemist and biologist should study.

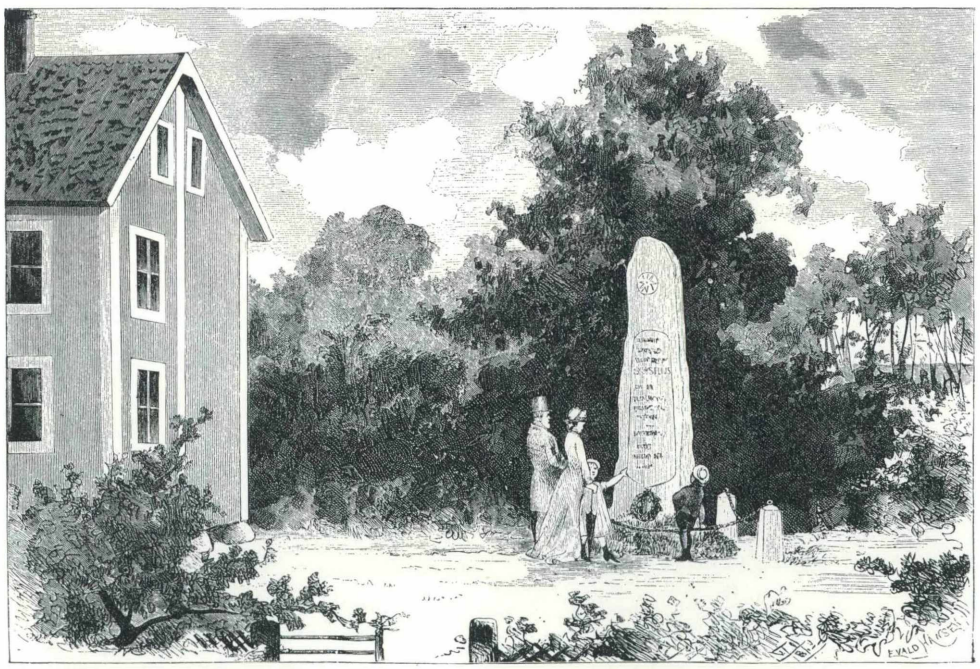
In a German work on the history of chemistry Berzelius's broad register in the realm of science is characterized in the following manner:

In order to present a complete survey of Berzelius's work it would be necessary to embrace the entire compass of chemistry. He has contributed to every conceivable branch of this science.

Today, in the face of the rapid expansion of chemical science, this might seem something of an exaggeration, but many of the questions which Berzelius dealt with in his time have attracted the chemists' interest long afterwards. This can be exemplified by the discovery and description of the pyruvic acid. This and closely-related fruit-juice acids are of major importance today in the study of the body's consumption of sugar and fatty acids.

Other fundamental definitions provided by Berzelius include his explanation of the phenomenon of chemical compounds with the same analysis but different properties. Berzelius defined this as *isomerism.*

A contribution of immense and lasting significance was made by Berzelius in his capacity as a member of the government committee which in 1829 published its report on the future pattern of "both



BERZELII MINNESSTEN I VÄFVERSUNDA, REST 100-ÅRSDAGEN AF HANS FÖDELSE DER. Teckned efter insänd fotografi.

On the centennial of Berzelius's birth a monument to his memory was erected at Väversunda Sörgård, where he was born. (From Ny Ill. Tidning 6 Sept. 1879)

academic and elementary education". The principal aim of this committee was to reform the established classical education system whose schools were little more than training establishments for the church and the law. Berzelius used all his authority and influence to introduce natural science in the school curricula. He encountered strong opposition from, among others, the members of the committee Johan Olof Wallin, later Archbishop, and the historian Erik Gustaf Geijer, who were resolved to retain the classical system. Berzelius made a crushing comment on the old system, observing that "the literary education bestowed upon the generation which is now responsible for public affairs: classical languages, belles lettres and history, has resulted in nine tenths of our civil servants and clergy being unable to explain why the moon changes its phases or why the mercury rises in the thermometer". Even though Berzelius did not succeed in establishing the place for chemistry and physics in the school curricula which he felt they deserved in the interests of practical education, he nevertheless made a start and in the course of time the manifest wisdom of his views was to become increasingly recognized.

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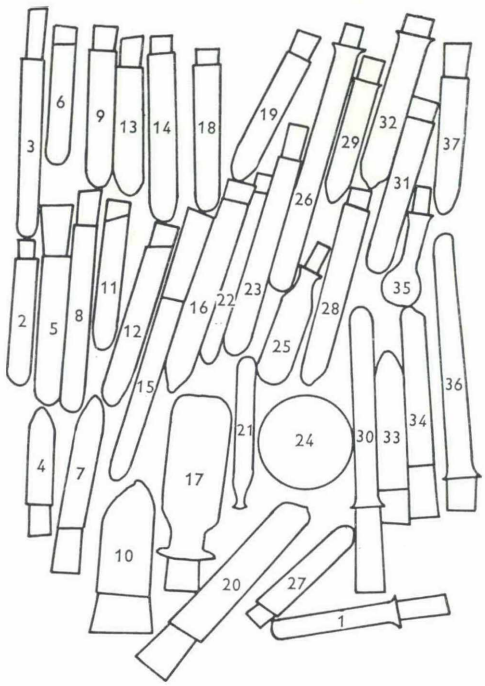
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Berzelius.



Berzelius's collection of vanadium compounds. Photography: Lennart Nilsson, Stockholm (Courtesy: Royal Academy of Sciences)



1 (439) $\dot{K}\dot{V}$
2 (451) $\dot{M}n\ \ddot{V}^2$
3 (434) Vanadium sulfide
4 (466) V (metallic)
5 (449) $\dot{B}a\ \ddot{V}^2$
6 (453) $\dot{M}n\ \ddot{V}$
7 (444) $\dot{N}a\ \ddot{V}$
8 (457) $\dot{\cancel{N}H}^3\ \ddot{V}^2$
9 (452) $\dot{V}\ \ddot{A}s$
10 (460) $\ddot{\cancel{V}}\ \ddot{S}^3$ (?)
11 (442) $\dot{N}H^4\ \ddot{V}$
12 (446) $\dot{V}^2\ddot{P} + \ddot{S}i^2\ddot{P}$
13 (436) $\dot{N}a\ \ddot{V} + 2\ \ddot{P}N\ddot{P}$
14 (450) $\dot{V}$
15 (464) $\ddot{V}$ precipitated from $\dot{K}\ddot{V}^2$
16 (456) $\ddot{S}r\ \ddot{V}\ \dot{P}^4$
17 (469) (?)
18 (465) $\dot{\cancel{N}H}^4\ \ddot{V}^2$
19 (448) $\dot{A}g\ \ddot{V}$
20 (440) $\dot{L}i\ \ddot{V}^2$
21 (468) (?)
22 (459) $\ddot{V}$
23 (458) $\dot{V}\ \ddot{S}$
24 (470) Melted vanadic-acid (?)
25 (437) $\dot{V}\ \ddot{\ddot{S}}$
26 (461) $\dot{K}\ \ddot{V}^2$
27 (441) $\dot{K}\ddot{S} + \ddot{V}\ddot{\ddot{S}}^2$
28 (443) $\ddot{S}i\ \ddot{V}$
29 (454) $\dot{C}a\ \ddot{V}^4$ (?)
30 (435) (?)
31 (463) $\ddot{S}\ \ddot{V}$
32 (447) $\ddot{V}$
33 (462) $\dot{N}\ \ddot{V}^2$ (?)
34 (438) $\dot{K}\ \ddot{V}^2$
35 (467) (?)
36 (455) $\dot{K}\ \ddot{V} + 4\ \ddot{\ddot{S}}$
37 (445) $\ddot{V}\ \ddot{\ddot{S}}$