

NILSON MEMORIAL LECTURE.

(DELIVERED ON JULY 5TH, 1900.)

By OTTO PETERSSON, Professor of Chemistry in the University of Stockholm.

LARS FREDRIK NILSON, born in Ostergothland in 1840, received his education at the high school of Wisby, on the island of Gothland, where his father possessed a large farm, Rosendal. The beautiful scenery and luxuriant vegetation of the sunny island in the Baltic, as well as the historical traditions attaching to its grand mediæval monuments now in ruins, left an impression upon the boy's mind never forgotten in after life. It is, in fact, impossible to understand the character and life-work of Nilson without taking into account his ardent attachment to the island where his youth was spent. As a chemist, he devoted himself with predilection to such investigations as had a bearing upon the development of the great but neglected agricultural resources of Gothland. I shall have more to say of this later; suffice it here to mention that the sugar industry, now so flourishing, and the cultivation of the sugar beet on that island were introduced on his initiative. Still Nilson had no leaning towards commerce; like the true man of science he was, he contented himself with being the adviser and promoter of economic progress. Although his occupations in Stockholm only allowed him time to make a short visit yearly to Gothland, yet he retained until the end of his life the management of a little farm there, which was his inheritance or patrimony, his part of the ancestral soil.

In 1859, at the age of 19, Nilson became a student at Upsala, his studies being directed towards biological science, especially zoology and geology, for which he obtained high marks in the examinations. Although his mineralogical study compelled him to acquire some knowledge of chemistry, he seemed at that time to entertain no special predilection for it. This work, however, brought him into personal contact with the director of the chemical laboratory of the University, Lars Fredrik Svanberg, whose well-known research upon molybdenum was carried out in conjunction with Struve in 1848 in Berzelius' laboratory in Stockholm. Svanberg had been a military engineer until Berzelius, who recognised his great ability as a mineralogist and his extraordinary analytical skill, offered him a place in his laboratory. Their acquaintance soon deepened into a lasting friendship, and greatly did the old master of science need the support of his strong-minded friend in the last critical years of his life, when his system of chemis-



L. F. Nilson

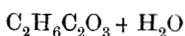
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try, once so firmly established, seemed to be on the point of giving way, attacked as it was from all sides by the advocates of the metaleptic and type theories.

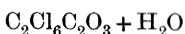
After Berzelius' death, Svanberg was nominated Professor of chemistry in Upsala (1853), and entrusted with the task of erecting a new institution with laboratories for chemistry, mineralogy, and physics. His aim was to raise the study of chemistry at the University, which had flourished under Torbern Bergman, but during the succeeding sixty years had become utterly neglected. This was not easy to accomplish, although Svanberg in many respects possessed excellent qualifications for it; he had an ardent and unselfish devotion to his science, he owned the greatest collection of chemical literature ever possessed by a private person in Sweden, and his phenomenal memory embraced the entire development of chemical science from the first beginning of a rational theory until the time of Berzelius' death. Bearer of the great traditions of the Berzelian era, he, however, had not the power of carrying to victory the ideas which he had defended in company with his illustrious friend.

The question pending at that time was the constitution of the organic bases and acids. Berzelius and Svanberg interpreted both as combinations of an inorganic base or acid with an organic compound, which played the part of 'copula.' Examples of such coupled combinations were to be found also in inorganic chemistry. The first ammoniacal platinum base discovered by Magnus was platinous chloride coupled with ammonia.* Ethylamine, in the words of Berzelius, was "mit ætheren gepaartes Ammoniak."† In close analogy to hydrofluosilicic acid, which was interpreted as hydrofluoric acid coupled with silicon fluoride, $2\text{HF}, \text{SiF}_4$,‡ acetic acid was regarded as a copula of oxalic acid with ethane, trichloroacetic acid, a copula of oxalic acid with carbon sesquichloride, &c.

It seemed, in fact, to be a desperate position to uphold the apparently extravagant formulæ



and



against the great generalisations of the type theory of Dumas and Williamson expressed in the symbols



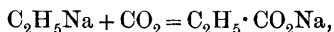
Still there was in Berzelius' formulæ, in spite of their errors with regard to atomic weights and to the part played by water in the

* PtClNH_3 , according to Berzelius.

† $\text{NH}_3\text{C}_4\text{H}_4$, according to Berzelius.

‡ $3\text{HF}, 2\text{SiF}_3$, according to Berzelius.

constitution of the acid, a germ of truth, and a possibility of progress which the type formulæ lacked. It was Kolbe who was destined to bring out the whole purport of Berzelius' conceptions concerning the copulated organic compounds. In a classical investigation executed partly in Playfair's laboratory in London, and partly in Bunsen's laboratory in Marburg, Kolbe, in 1849, the year after Berzelius' death, proved that acetic acid by electrolysis gave birth to ethane, carbonic acid, and hydrogen * (*Annalen*, 1849, 69, 252). The further steps of progress from Berzelius' and Kolbe's point of view to that of the modern theory of organic chemistry were the synthesis of sodium propionate by Wanklyn,



and the brilliant discovery of the valency of the elements by Frankland.

From the date of Berzelius' death, Svanberg abandoned experimental work, feeling that his mission was to organise the teaching of chemistry on a broad basis in the new laboratory of the university, and to arouse interest in the study of his science. Like the seer of old, he was content to show to the next generation of his people the path into the land of promise. There can be no doubt that he succeeded, for most of the chemists who now hold the position of teachers at our academies or leaders of the industrial or metallurgical works of our country are pupils of Svanberg. The names which will be most familiar to you are Cleve, Nilson, and De Laval the reformer of the dairy industry of the world.

In 1865, Nilson was ready to take his degree. The examination regulations in Sweden are somewhat complicated, being specially drawn up with a view of insuring that the claims of the humanities shall not be subordinated to those of empirical science; the candidates for the Doctorate of philosophy, therefore, were obliged to undergo examinations in history, philosophy, languages, &c., in addition to their chief subject. The examination itself was a mere formality, but it was preceded by private examinations in every subject, and all these had to be passed within a certain time, usually six months, previous to the day of examination, if not, the whole procedure had to be repeated. Nilson was ready for examination when bad news arrived from home. His father had had a stroke of apoplexy, and the work on the farm was much impeded by his illness. Nilson himself was at that time very delicate in health, suffering from bleeding from

* It scarcely needs to be mentioned that neither Berzelius nor Kolbe then distinguished between the radical methyl and the compound dimethyl or ethane, the distinction being first made by Frankland several years afterwards.

the lungs. To leave Upsala some weeks before the examination meant to postpone it for a year, or indeed for ever, uncertain as it was if he could hope to return any more. Nilson, however, did not hesitate; he went over to Gothland, and undertook the management of the farm, himself labouring in the fields. When his father, some months afterwards, recovered, to the happy astonishment of the family, Nilson could inform him of two things: firstly, that the harvest was in the barns in the best condition, and the soil prepared and sown for the autumn; secondly, that he had succeeded without any technical assistance in installing the engine and threshing machinery which had just arrived from England—the first machinery of that kind to be introduced into Gothland—and that it had worked excellently. “This”—Nilson wrote to a friend—“awakened the liveliest astonishment in my father.” Shortly afterwards Nilson returned to the university, where a richer harvest was ripening for him.

He returned another man than he went. The healthy country life, and labour with its responsibilities and its success had changed the sickly youth, overburdened with mental exertion and doubt about his capacities and calling in life, into a strong, resolute man who knew his aim and how to realise it:

“Der Riese hat die Mutter Erde berührt”

“Und es wachsen ihm neu die Kräfte.”

From that time until thirty-two years afterwards, when he literally broke down under the burden of labour, he was never ill, and never tired. Without any difficulty, he passed his examination, obtained his degree with a dissertation on thialdine, and a year later became head of the laboratory as chief assistant and demonstrator of chemistry.

A few words concerning the laboratory of Upsala thirty to forty years ago may not be out of place. There was the large and very crowded common laboratory room irreverently called “the stable” by the students on account of the composition of its atmosphere in which free ammonia entered in a not inconsiderable proportion. Nilson here appeared as a calm and patient teacher rather sparing of words, preferring to give an experimental demonstration or practical advice instead of long verbal explanations. Inside was the assistants’ room and Svanberg’s private laboratory, where those occupied with scientific investigations had places. Everything here reminded one of Berzelius. There were the balances, the blowpipes, the platinum crucibles—some of the first ever made—that had belonged to him. On the shelves there were some of his preparations, venerable relics from the days of his discovery of selenium thorium, &c. At a certain hour of the day Svanberg appeared in his old military coat—the abomination of his

august colleagues of the academical *consistorium majus*—eager to know the progress of every new experiment, himself the most enthusiastic of all when success attended the endeavours of his pupils. His rooms on the floor above the laboratory were lined with bookshelves containing thousands of volumes arranged in double rows on each shelf. These treasures of the chemical literature of bygone centuries were destined to belong to the University after his death, and were at the disposal of his assistants and pupils during his lifetime. The circle of scientific students in Svanberg's laboratory was united by ties of friendship in the hours of labour and of pleasure. As work usually continued until late in the evening, there seemed to be little time left for pleasure, but the balance between work and pleasure was kept up in another way. Whilst it was customary in the private laboratory where Nilson presided to enliven the hours of work with conversation, anecdotes, puns, occasionally by a song, &c., it was considered unfitting to introduce scientific matters into the conversation of leisure hours. Nilson positively did not admit it, and woe to him who dared to speak of political or philosophical matters when Nilson intended to be merry. And he was always merry when he was with his friends, the merriest of them all. He had a thousand devices for putting a stop to a conversation which threatened to take a tiresome turn. He would, for example, sit listening for a while with a grave face, and then interpose with a short nonsensical observation, delivered with great solemnity in the accents of some political or scientific worthy of pedantic fame, while a gleam of fun shot forth from under his heavy, dusky eyebrows. The effect was irresistibly comic, so much the more as it came unforeseen. His hearers were at first puzzled, then one chuckled, another laughed, and in a minute the impending political or philosophical discourse was drowned in a chorus of laughter in which Nilson's voice at last joined in accents swelling like big waves and rollers of an ocean of mirth.

Out of the great number of scientific researches undertaken by Nilson, I will speak only of some of the most important, in order to show what scientific impulses he received and how his life-work is connected with the work of the leading masters of his science in present and bygone ages.

In 1871, his first paper in inorganic chemistry "On the Sulphides of Arsenic" was published in the *Proceedings* of the Royal Academy of Sciences in Stockholm. This research was undertaken in order to complete the investigation upon sulphides and sulpho-salts which Berzelius had commenced in 1821—1826.

This period represents the most brilliant epoch in the history of Berzelius, when his generalising genius shone forth in its full vigour,

and made him for a time the undisputed authority on chemical theories. Until that time he had been an adversary of the conception of the binary composition of haloid salts, but in 1821 he at last admitted the cogency of the experimental proofs furnished by Sir Humphry Davy and Gay-Lussac of the elementary nature of the halogens and the binary composition of their hydrogen compounds HCl, HF, &c. His mind was then opened to a wider view of the nature of inorganic compounds which embraced all kinds of salts, and resulted in a new classification of the elementary and compound substances constituting the realm of inorganic chemistry. In Berzelius' Annual Report for 1826, his system of classification is enunciated in short and pregnant definitions: Elements are either positive (metallic) or negative (non-metallic).

Among the non-metallic elements are the two groups:

- (1) Halogens * (*Corpora halogenia*) which form binary saline compounds with the positive metals, and,
- (2) Amphids † (*Corpora amphigenia*) which form basic compounds with positive and acid compounds with negative elements.

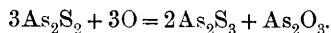
Berzelius says: "There are three classes of salts. The first class, which I denote as *haloid* salts, are combinations of an electro-positive metal and a halogen. The second class, which I denote by the name of *amphid* salts, are constituted of one base and one acid. There are four different amphid salts: oxy-salts, sulpho-salts, selenium salts, and tellurium salts. When we consider the influence this classification has exercised on the theory and the teaching of inorganic chemistry during the greater part of the nineteenth century, we can judge of the enthusiasm which greeted it at the time of its first appearance. Svanberg, however, considered that the analogies which Berzelius had found to exist between the salts of the amphid group needed elucidation and to some extent correction. At his suggestion Nilson undertook the study of the selenium salts and sulpho-salts, of which Berzelius had synthetically prepared 120 without, however, being able to enter upon a closer study of more than a small number of them.

According to Berzelius, there existed three kinds of arsenical sulpho-salts, namely, sulpharsenates, sulpharsenites, and hyposulpharsenites, and four sulphides, namely, As_2S_5 , As_2S_3 , As_2S_2 , and As_6S . Nilson showed that the hyposulpharsenites, as well as the sulphide As_6S , do not exist. The red or brown precipitate which separates out from boiling solutions of the trisulphide As_2S_3 in sodium carbonate consists of impure realgar, As_2S_2 , and the black sulphide, As_6S , which was supposed to arise from the decomposition of realgar with alkali, is a mixture of this substance with arsenic. He synthesised realgar in a number of different ways,

* Chlorine, iodine, fluorine (according to Berzelius, 1826).

† Oxygen, sulphur, selenium, and tellurium.

and found that this sulphide is liable to decomposition in air, whereby arsenic trisulphide, As_2S_3 , and arsenic trioxide, As_2O_3 , are formed,



This change seems to throw some light upon the genesis of orpiment in nature by metamorphosis and decomposition of realgar. In fact, orpiment seems to be a secondary product, since almost every crystal of realgar is found to be coated with a bright yellow deposit of the trisulphide, which increases in bulk with time. Of real sulpho-salts of arsenic derived from the tri- and penta-sulphide, Nilson synthesised a great number. Likewise he discovered the existence of new oxysulphides ($\text{As}_2\text{S}_2\text{O}_3$) and oxysulpho-salts of arsenic.

Nilson's next work, "Researches on the Salts of Selenious Acid," (*Nova Acta Reg. Soc. Ups. III*, 1875), may also be regarded as a complement to the work of Berzelius. In 1817, Berzelius discovered selenium and selenious acid,* of which he described a number of salts. For the most part he did not go beyond qualitative experiments, and only rarely stated the quantitative composition of a few salts (of sodium, barium, lead, silver) with a view of ascertaining the basicity of the new acid. Nilson considerably enlarged our knowledge of the neutral and acid combinations of selenious acid by accurate analyses of more than one hundred of its salts.

In the beginning of the seventies a new era dawned for inorganic chemistry with the discovery of the periodic relations of the elements by Newlands, Mendeléeff, and Lothar Meyer. The natural system of Mendeléeff in which the new idea for the first time had found its fullest and most perfect expression, completed and supplanted Berzelius' classification of the elements just as the natural system of plants by Jussieu had supplanted the Linnæan system of the vegetable kingdom. Moreover, the periodic law as promulgated by Mendeléeff invited experimental inquiry. There were new elements to discover, atomic weights to correct, elements of doubtful chemical character to study.

The crucial test of the periodic law seemed to lie with the elements of the rare earths. As these elements until then had been found to exist almost exclusively in Scandinavian minerals in which the oxides yttrium, erbium, terbium, cerium, lanthanum, didymium, and thorium had been discovered by Gadolin, Berzelius, and Mosander, it seemed incumbent upon the Swedish chemists to take up the intricate problem once more. Cleve and Höglund undertook a research upon yttrium, thorium, and erbium, which inaugurated the well-known series of investigations still being carried on by Cleve and his pupils.

Shortly afterwards Nilson began the study of the rare earths con-

* "Selenic" acid in the terminology of Berzelius.

tained in euxenite, of which mineral he had received a considerable quantity from Professor Waage in Christiania. He soon succeeded in extracting a large quantity of the crude oxides, and these were submitted to the fractionating process invented by Berlin, and afterwards practised by Bahr and Bunsen, namely, heating the nitrates until partially decomposed. Nilson began this work with a special purpose in view. He and I had agreed to make a research in common upon the physical and chemical constants of such elements and compounds of the rare earths as were considered to have a special bearing upon the periodic law of Mendeléeff. The material for this investigation was to be partly beryllium oxide, which we prepared in common from crude beryl, and partly such oxides of the rare elements as Nilson hoped to separate in the purest possible condition from the euxenite oxides by systematic fractionation.

The bivalency of beryllium, with the atomic weight 9.2, was a cardinal point of the periodic law. The existing experimental determinations of the atomic heat of metallic beryllium seemed to confirm this view, since the specific heat was found to be 0.642 which, if $\text{Be} = 9.2$, makes the atomic heat 5.9 in accordance with the criterion of Dulong.

Nilson and I prepared metallic beryllium from equivalent quantities of beryllium chloride and sodium heated to redness in an hermetically closed crucible of wrought iron. The metal thus obtained had a specific heat 0.41, or only two-thirds of that formerly found, a value which agrees far better with the view that the element is trivalent with an atomic weight of about 13.8, contrary to the requirements of the periodic law.

Still the question of the real atomic weight and valency of this element could be considered open to doubt, since there existed the possibility that beryllium might be an exception to the rule of Dulong, like carbon, boron, and silicon, and that its specific heat would be found to increase with temperature. This explanation received support from a remarkable discovery by Brögger and Flink, who, on examining the crystallised metal prepared by us, found it to possess the same crystalline type (of the hexagonal system) as the bivalent metals, magnesium, zinc, and cadmium. We resolved therefore to determine the specific heat of the metal at higher temperatures than 100° , and also the vapour density of its chloride, in order to finally decide the chemical character of the element.

We found that the specific heat increases rapidly with rise of temperature, from 0.42 between 100° and 0° to 0.50 between 300° and 0° . Professor Humpidge, of Aberystwyth, who, immediately afterwards, with great experimental skill revised the physical constants of this element, arrived by other methods than ours at concordant results.

The following table contains the numbers thus found representing the atomic weight and specific heat of beryllium :

Atomic weight = 9.081 ($H=1$), Nilson and Pettersson (*Ber.*, 1880, 13, 1451; 1884, 17, 987), = 9.027 ($H=1$), Krüss and Morath (*Annalen*, 1890, 262, 38).

Density d $20^{\circ}/20^{\circ}$ = 1.85, Humpidge (*Proc. Roy. Soc.*, 1885, 39, 4).

Specific heat :

Temperature.	Nilson and Pettersson. Ice-calorimeter.	Temperature.	Humpidge. Method of mixtures.
0—100°	0.4246	11—100°	0.4286
		11—145	0.4515
		11—193	0.4696
0—300	0.5060	15—240	0.4885
		14—312	0.5105
		11—360	0.5199
		17—447	0.5403

The vapour density of the chloride was found to be (Nilson and Pettersson) :

Temperature.	Density.	Temperature.	Density.
490°	6.700	745°	2.753
520	4.174	812	2.793
589	3.067	1080	2.684
597	3.031	1115	2.779
604	3.090	1184	2.824
686	2.853	1502	2.791
720	2.926		

As the determination of the vapour density of this chloride was the first of a great series of similar experiments, a few words about the methods employed may find a place here.

The determination of vapour densities at high temperatures was at that time (1880—1890) a matter of unusual interest to chemists, since Victor Meyer (1876) had improved the experimental technique by introducing the principle of displacement (*Luftverdrängungsverfahren*), devised by Dulong (compare Dumas, *Compt. rend.*, 1874, 78, 536) into use in a practical and elegant form. Although this method led Meyer and his pupils to some of the most important discoveries of that time, among which the breaking up of the molecules of the halogens at high temperatures was the most remarkable, his method was by no means adapted for accurate measurements. The methods which we employed in the determination of the vapour density of beryllium chloride and subse-

quent experiments with the chlorides of aluminium, indium, germanium, gallium, &c., were described in a paper entitled "Ueber ein neues mit exacter Temperaturbestimmung verbundenes Verfahren zur Feststellung der Dampfdichte flüchtiger Körper" (*J. pr. Chem.*, 1886, [ii], 33, 1). The platinum vessel in which the chloride was allowed to evaporate also acted as the bulb of a gas thermometer of the compensatory type devised by me (*J. pr. Chem.*, 1882, [ii], 25, 102). In our experiments with beryllium chloride and other metals, we found it to be an indispensable condition for obtaining constant results (1), to prepare the chloride from the pure metal by means of dry hydrogen chloride; (2), to employ platinum tubes for the preparation of the chloride and platinum bulbs for the density determination; (3), to evaporate the substance in an atmosphere of an absolutely dry indifferent gas (usually carbon dioxide).

In beryllium chloride, as in most other volatile substances, there seems to exist at low temperatures an unstable association of molecules. For the study of this transitory state, the displacement method of Dulong—V. Meyer is not sufficient, and must be supplemented by that of Dumas. We employed for determinations of the vapour density of chlorides, &c., at such temperatures the modification of Dumas' method introduced by O. Pettersson and G. Ekstrand (*Ber.*, 1880, 13, 1191). From 730° upwards, beryllium chloride was found to have almost exactly the constant density 2.77, as calculated for the molecule BeCl_2 .

While the beryllium work was proceeding, important discoveries had been made in the chemistry of the rare earths. The mineral samarskite from N. America was found to contain, besides the element terbium already announced by Mosander,* a whole group of new elements. The first discoveries of these earths were due to Delafontaine in 1878. The confusion about the names, the atomic weights and characteristic absorption bands of the new elements of the samarskite group, which at first appeared in the descriptions given by Delafontaine, Laurence Smith, and others, gradually subsided under the critical scrutiny of Roscoe, Soret, Lecoq de Boisbaudran, and Marignac.

Moreover, the gadolinite group of earths, which was considered until then to contain only two elements, yttrium and erbium, began to break up into a number of new earths. Soret had announced the existence of a new element, X (later identified with the holmium of Cleve) rich in absorption bands, and Cleve found that the bands of the erbium of 1873, of the atomic weight 170.5, began to split up into one group belonging to an element forming a red oxide with the characteristic emission spectrum (by incandescence) of the old erbium, and another group of only two absorption bands in the visible spectrum

* Mosander's denomination for this element was "erbium."

belonging to a colourless oxide, to which he later gave the name thulium. The most promising discovery was, however, due to Marignac, who in 1878 found that the entire group of absorption-bands of the erbium earths could be eliminated by successive fractionating, whilst the atomic weight of the remaining oxide increased. He justly concluded that a new element of high atomic weight (172·5) must exist, which he denominated ytterbium. From want of material, he could not purify and isolate its oxide; he therefore exhorted such chemists as possessed a greater supply of material to continue the investigation of the new earth. Now it became Nilson's turn to earn the reward of his long labour; he had started his work with a greater quantity of raw material than other chemists of that time, and he had worked, as was his wont, in the most methodical manner. Moreover, the material, oxides from euxenite, which he treated was singularly rich in the elements of higher atomic weight of the gadolinite group of earths. The consequence was that he could fractionate easily a considerable quantity of nitrates up to the point indicated by Marignac, where the absorption-bands began to vanish, and the atomic weight of the metal amounted to 172·5. Before he had reached that point, however, Nilson made the startling observation that there separated out, among the insoluble basic salts, the nitrate of a less basic metal of lower atomic weight. The equivalent weight of the oxides in the insoluble part of the decomposing nitrates had a tendency to sink instead of to rise. He immediately concluded that, together with ytterbia, a new oxide must exist. The atomic weight of the elements contained in these fractions rapidly sank to 134, and even lower, whilst the atomic weight of the element in the other part of the fractions slowly rose to 173·01, the oxide became snow-white, and all absorption-bands vanished from the solutions of its salts. Nilson thus had succeeded in isolating two of the best defined elements of the rare earths, ytterbium (*Ber.*, 1879, 12, 550) and scandium (*ibid.*, 554). Both are characterised by brilliant emission spectra studied by R. Thalén, and by highly interesting chemical properties. Both elements fill prominent places in the third group of the periodic system, and scandium is especially remarkable, as it is identical with Mendeléeff's hypothetical element ekaboron.

The intention of Nilson and Pettersson to isolate the elements of such oxides as could be obtained in a state of chemical purity from the rare earths and determine their physical and chemical constants was not to be fulfilled. In 1881, I was called to undertake the duties of Professor of chemistry at the newly instituted Stockholms Högskola, Nilson remaining in Upsala as Professor of analytical chemistry. Before parting, we found time to determine the specific volume and heat of the oxides and sulphates of all earth-metals then known (*Ber.*, 1880, 13, 1459).

Occupied as he was with the discovery of ytterbium and scandium, Nilson still found time to publish some important researches upon the chemistry of other members of the rare elements.

Already, in 1877 (*J. pr. Chem.*, [ii], 15, 177), he had taken up the study of the platinichlorides of these elements commenced by Cleve, Jolin, and others.

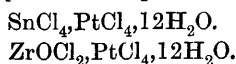
The platinichlorides are of three general types :

- A. $\left\{ \begin{array}{l} 2\text{RCl}, \text{PtCl}_4 \\ \text{RCl}_2, \text{PtCl}_4 \end{array} \right\}$ (normal platinichlorides).
 B. $\text{RCl}_3, \text{PtCl}_4$ ($\frac{2}{3}$ " ").
 C. $\text{RCl}_4, \text{PtCl}_4$ ($\frac{1}{2}$ " ").

To A belong the salts of uni- and bi-valent metals, such as potassium, barium, &c. The platinichloride of beryllium, $\text{BeCl}_2, \text{PtCl}_4, 8\text{H}_2\text{O}$ (Marignac and others), belongs to this type.

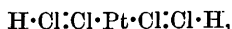
To B belong the platinichlorides of the trivalent elements, aluminium, chromium, iron (Nilson), didymium, erbium, cerium, lanthanum (Cleve, Jolin, and others). Yttrium and indium are exceptions, their platinichlorides being represented by the formulæ $4\text{YCl}_3, 5\text{PtCl}_4, 52\text{H}_2\text{O}$ (Cleve, Nilson), $\text{InCl}_3, 5\text{PtCl}_4, 36\text{H}_2\text{O}$ (Nilson).

Of the type C ($\frac{1}{2}$ -normal platinichlorides), only one member was known, namely, the thorium salt, $\text{ThCl}_4, \text{PtCl}_4, 12\text{H}_2\text{O}$, described by Cleve. Nilson found that the quadrivalent metallic elements as a rule form platinichlorides of this type, for example :



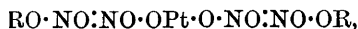
The platinichlorides of metallic elements thus furnish a very characteristic indication of their valency.

The same holds also to a certain extent with regard to the platinochlorides, a class of compounds which, before Nilson's time, had been very little studied. Nilson prepared (*J. pr. Chem.*, 1877, [ii], 15, 260) the corresponding chloroplatinous acid,



which exists only in dilute solution, and on evaporation in a vacuum decomposes, losing hydrogen chloride forming the compound $\text{H} \cdot \text{Cl} : \text{Cl} \cdot \text{PtCl}$, which at 100° is transformed into platinous chloride, PtCl_2 .

From the same year (1877), dates an important research upon plato- and diplato-nitrites. The constitution of the platonitrites, first studied by Lang (*J. pr. Chem.*, 1861, 83, 415), had been interpreted by Blomstrand (*J. pr. Chem.*, 1871, [ii], 3, 186) to be

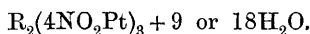


or compounds of platotetranitrosylic acid.

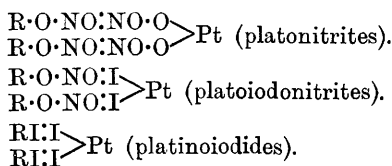
The platonitrites are beautifully crystallised salts. Nilson found that in some cases they decompose into diplatonitrites, nitrous acid, and nitrites (*Ber.*, 1876, 9, 1722).



In this way, the diplatonitrites of silver, beryllium, and iron (Fe''') are formed. The tervalent metals, yttrium, erbium, lanthanum, and didymium form normal platonitrites of the composition



Nilson found that the platonitrites of potassium and barium are changed into iodoplantonitrites (*Ber.*, 1878, 11, 879) if treated with iodine in alcoholic solution. This new class of salts occupies an intermediate position between the platonitrites and platinoiodides.



In 1882, Nilson published his first researches upon thorium which he later completed in conjunction with G. Krüss (*Zeit. physikal. Chem.*, 1887, 1, 301). He succeeded in obtaining metallic thorium and determining the vapour density of its chloride.

In preparing pure thoria, Nilson experienced the difficulty of removing from it the last traces of cerium dioxide, which most pertinaciously clings to it. The fact that this was successfully overcome in 1883 has been of some importance in the industrial rivalry of the great incandescent lighting companies, since the first patent claimed the employment of pure thoria, which is, however, by no means a fit material for incandescent lamps.

Nilson and Krüss (*Zeit. physikal. Chem.*, 1887, 1, 391) also tried to isolate niobium from potassium fluoroniobate, but, like Marignac, they obtained the hydride, NbH , instead of the metal. The specific heat of this hydride was found to diminish considerably with rise of temperature, as shown by the following numbers:

Temperature	0—100°	0—210°	0—301°	0—440°
Spec. heat of NbH	0.0977	0.0925	0.0871	0.0834
Molecular heat of NbH ...	9.3	8.8	8.3	7.9

In the course of his long work upon the elements of the rare earths, Nilson had acquired a rich collection of their oxides, extracted from

different minerals. When Nilson and Krüss (*Ber.*, 1887, 20, 3067) spectrometrically compared the relative intensity of the characteristic absorption-bands of holmium, thulium, didymium, erbium, samarium, &c., in the solutions of basic nitrates of oxides derived from different minerals, they discovered remarkable variations, similar in character to those observed in 1886 by Crookes (*Proc. Roy. Soc.*, 1886, 40, 563) who stated that it was possible to eliminate band after band from the original didymium spectrum until only a single band λ 443 was left. From similar observations, Nilson and Krüss drew the following conclusion: "Nach obigen Auseinandersetzungen hätten wir an Stelle des Erbiums, Holmiums, Thuliums, Didyms, und Samariums, die Existenz von mehr denn zwanzig Elementen anzunehmen."

Few chemists of the present day will admit the strictness of this conclusion. There are many facts indicating that absorption bands as well as luminous bands of fluorescence cannot be regarded as essential characteristics of elementary substances. The experiences of Sorby with jargonium, as well as the observations of Liveing upon the variations occasioned by the nature of the solvent, and by impurities, on the intensity of absorption bands, are instructive in this respect. We can also hope that the study of the radio-active substances which are found to accompany the rare elements may throw light upon this question, so that the nebula of elementary matter which now seems to exist within the erbium and other groups will dissolve into well-defined elements.

Once more, after Nilson had taken up his residence at Stockholm as Professor of agricultural chemistry, an opportunity arose for carrying on the investigation upon the physical and chemical properties of the rare elements which we had planned in earlier days. The time for our joint work was, however, very limited owing to official duties, and the fact that new scientific interests had arisen on both sides. Nilson's efforts were concentrated upon the problems of augmenting the harvests and the fertility of the soil, whilst mine were concerned with the physical and chemical properties of the ice and water of the ocean. Still, we were able to spare about three weeks every year for research, and of these we made five by working late.

Much uncertainty prevailed with regard to the formulæ and molecular weights of the chlorides and similar compounds of aluminium, indium, gallium, iron (Fe'''), and chromium. The vapour densities of aluminium chloride and ferric chloride had been found by Deville and Troost (*Ann. Chim. phys.*, 1860, [iii], 58, 283) as well as by V. Meyer (*Ber.*, 1879, 12, 1199) to correspond with those required for the formulæ Al_2Cl_6 and Fe_2Cl_6 , whilst indium chloride, according to V. Meyer, must be represented by the formula InCl_3 . About gallium chloride opinions were divided, Lecoq de Boisbaudran's determinations (*Compt. rend.*, 1881, 93, 329) being in accordance with the

doubled formula Ga_2Cl_6 , Friedel's (*ibid.*) more with GaCl_3 . The question seemed the more ambiguous as the determinations according to Dumas' method always seemed to give greater values for the density than those obtained on Dulong's principle at the same temperatures.

We found that no range of temperatures exists through which the vapour density of these chlorides is sufficiently constant to warrant the doubled formulæ Al_2Cl_6 , In_2Cl_6 , &c. Whilst the density of aluminium chloride as observed by Deville and Troost is 9.20 between $350-440^\circ$ (corresponding with that required for the formula Al_2Cl_6), it increases below that temperature, and decreases above it (*Zeit. physikal. Chem.*, 1889, 4, 206) until at about 800° (or even below that temperature, if evaporated in an indifferent gas) the value 4.60* is obtained which remains constant for some hundred degrees.

The vapour of aluminium chloride at low temperatures—like that of acetic acid studied by Cahours—consists of unstable associations of molecules, $n\text{AlCl}_3$, which generally undergo dissociation into AlCl_3 as the temperature increases. This dissociation depends, not only upon temperature, but also upon pressure, consequently dissociation will be found to be more advanced at a certain temperature if the chloride is evaporated in an atmosphere of an indifferent gas, as is the case in experiments with the displacement method. This accounts for the discrepancy between the vapour densities determined on Dumas' and on Dulong's principles (*Zeit. physikal. Chem.*, 1889, 4, 224).

At very high temperatures we observed a gradual breaking up of the molecules of these chlorides, characterised by a slight diminution of the vapour density. The temperature at which this chemical dissociation begins is very different in different chlorides, for while beryllium chloride maintains its normal vapour density 2.77 up to $1500-1600^\circ$, aluminium chloride begins to show signs of chemical dissociation above 1000° , and gallium chloride below this.

We found that indium has three chlorides: InCl_3 , InCl_2 , InCl (*Trans.*, 1888, 53, 814; *Zeit. physikal. Chem.*, 1888, 2, 65), and gallium two chlorides: GaCl_3 and GaCl_2 , each characterised by the normal vapour density required for the respective formulæ. Thus it is proved that a metal such as indium can exist in gaseous compounds as a uni-, bi-, and ter-valent element.

In 1886, Clemens Winkler discovered germanium, the ekasilicon of Mendeléeff, and entrusted to us the determination of its physical constants, namely, the specific heat of the metallic element and the vapour density of its chloride, GeCl_4 , and sulphide, GeS . The results of this investigation are published in 1887 in a paper entitled: "Ueber

* The theoretical value for AlCl_3 is 4.60.

einige physikalische Constanten des Germaniums and Titans" (*Zeit. physikal. Chem.*, 1887, 1, 27).

From 1878 to 1883, Nilson filled the position of Professor of analytical chemistry at the University of Upsala. In 1883, he became Professor of agricultural chemistry at the Royal Academy of Agriculture in Stockholm. He devoted himself to his new duties with the same energy and interest which he had shown in his investigations in theoretical chemistry. In the first place, he had to organise the laboratory and make arrangements for experiments with plant culture in accordance with modern methods, and then he elaborated minute directions for the analytical work in the different chemical stations of Sweden, of which he was inspector. He was consulted in all questions of importance concerning agricultural or technical legislation, and his decision on such questions was always founded upon exact and original experimental investigation, as will be found from his reports upon the analysis of butter and of milk, or his examination of the lactocrite method, and the efficiency of the different mechanical methods of separating the fatty matter from milk, or his investigation in reference to urban sanitation.

It could hardly be expected that, in addition to this official work, he could find time and opportunity for experimental scientific investigations in agricultural chemistry, nevertheless, there are not less than 57 separate papers upon such topics published by him in the *Journal* of the Royal Academy of Agriculture.* I must confine myself here to mentioning only two or three of these investigations.

In the first place, both on account of the intrinsic value of the analytical work bestowed upon the subject, and on account of its practical importance, his treatise on the possibility of introducing the culture of the sugar beet into Gothland must be mentioned. The climate and the arable land of Gothland are in themselves favourable to the culture of this plant, as pointed out long before by A. Müller and others. More than 30,000 hectares, or about one-ninth of the area of this island, consist of almost sterile swamps, the soil being composed of a thin layer of humus formed by decayed vegetable matter which has grown in the stagnant water in the hollows of the plateau of Silurian limestone forming the geotectonic framework of the island.

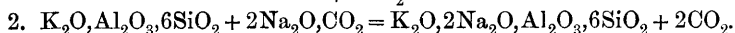
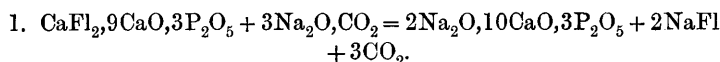
Nilson proved by chemical analysis as well as by cultural experiments, that the black soil of these swamps is unusually rich in lime and nitrogenous humous substances, containing as much as 4 or 5 per cent. of nitrogen. The sterility of the soil in its natural state is due to the almost total absence of phosphoric acid, and, in some measure, also to the scarcity of potassium. If this want is supplied by artificial

* See *Kongl. Landtbruksakademiens Handlingar och Tidskrift*, 1883–1898.

manuring, the richest crops of corn, rape, and sugar-beet can be obtained. The intelligent farmers of Gothland, to their great economic profit, hastened to follow Nilson's advice ; the barren ground of the swamps is now drained and sown with corn and rape, and, to some extent also, with sugar-beet.

An indispensable condition for maintaining a rational culture of the soil is to have a supply of natural or artificial calcium phosphate. The annual import of phosphates into Sweden is equivalent to more than 18 million kilograms of phosphoric oxide, whilst only 2 or 3 million kilograms are produced in the country, the condition of things not being favourable for the manufacture of basic phosphate. In the Northern provinces of Sweden, especially in the great iron-ore district of Gellivara, apatite occurs so intimately mixed with iron ore, that the latter must be separated from it either by washing or by magnetic extraction. It occurred to Professor J. Wiborgh that the apatite powder could be converted into tetraphosphate by ignition with alkali. When the first experiments had proved successful, Nilson, at Wiborgh's request, took over the analytical investigation and biological experiments with the new fertiliser. Thirty parts of soda are heated to about 900—1000° with 100 parts of powdered apatite, which, on the average, contains about 17 per cent. of felspar.*

The chemical reaction is :



The product, which consists of neutral silicates and tetraphosphates of calcium, sodium, and potassium, is insoluble in water, but is still assimilable by plants more completely than ordinary tetraphosphate obtained by the Thomas-Gilchrist method. For the manufacture of Wiborgh phosphate a great industrial establishment is now in working at Luleå.

Nilson was a member of the Chemical Societies of England, France, and Germany, and of nearly all learned Societies and Academies of the Scandinavian countries. He was a most active and influential member of the Royal Academies of Science and of Agriculture in Stockholm, but as much as possible avoided representative duties, declining, for example, much to the disappointment of his colleagues, to undertake the Presidency of the former. He was not a brilliant lecturer, but no one was listened to with greater attention.

* The presence of silicate—as might be foreseen from the recent researches of Wagner and others—is essential for the assimilability of the tetraphosphate by plants.

In the scientific world, it awakened not a little surprise commingled with regret that Nilson, in 1883, a few years after his discovery of ytterbium and scandium, left his work in the field of theoretical chemistry, where he had met with such brilliant success, in order to take up the seemingly modest occupation of an agricultural chemist. His friends knew that this involved a great sacrifice on his part, but they felt no astonishment at his resolution. They knew that with Nilson the sense of duty was paramount, and the desire of success of secondary importance. His country needed him to fill that place—that was all. Besides, there dwelt within him an innate love of living nature; he liked not only to study the abstruse problems of natural science, but he was also an admirer of nature herself. He was fond of farming and gardening; he loved flowers, and had a singular talent for arranging them. In this art he considered his own taste infallible, he could admit the talent of others, but he acknowledged the superiority of none. I can see him on one of those days when he had invited a party of friends to his hospitable house, entering the room with a huge burden of flowers from the meadow or garden, arranging them deliberately in his own original fashion, before he came forth beaming with pleasure to welcome his guests.

The burden of labour which his excellent constitution had long sustained without any sign of giving way, at last became too heavy even for his powers. His friends felt anxious, but Nilson showed no anxiety; his trustful sanguine temperament, which, throughout his lifetime made him look upon every event from its hopeful side and upon every man from the best side of his character, obscured from his eyes the approach of death, and let the forebodings which inevitably precede it pass by unheeded. He was spared from long lingering and suffering. There was a sudden blow, a short struggle, and all was over.
