Gustavus Hinrichs and His Charts of the Elements

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Abstract

In this paper, I analyze the efforts of the German-American chemist Gustavus Detlef Hinrichs (1836–1923) to construct a periodic system between 1867 and 1869. Included is a transcription and translation into English of major sections of his *Programme der Atomechanik* (1867), and a discussion of Hinrichs's "pantatom" theory of matter. My principal conclusions are: (1) Hinrichs's chart of 1867 is actually a double spiral that begins in a clockwise fashion but then reverses direction and continues in a counterclockwise direction, (2) the nitrogen and oxygen groups are swapped because Hinrichs felt that that order resulted in more consistent trends in the stoichiometries of the highest oxides, (3) in his chart the trigonoids and tetragonoids each subtend one-third of a circle, and the spokes are arranged so that the maximal valences of the elements increase from right to left, (4) Hinrichs devised an ingenious theory to account for isomorphism, (5) the transition elements in Hinrichs's 1869 table are listed in reverse order for the same reason that the spiral in his 1867 chart reverses direction, (6) the transition elements in the 1869 system are arranged in a slanted fashion to reflect their relative atomic weights, whereas other elements are not arranged in this way, possibly owing to a printer's omission, (7) Hinrichs was the first to point out that one advantage of the "long" form periodic tables is that the metals and non-metals can be separated by a single line, and (8) simultaneously with Meyer and Mendeleev, Hinrichs also pointed out the periodic relationship of atomic volume to atomic weight, but only in his oral presentation to the AAAS meeting of August 1869.

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7.1 Introduction

Of the pre-Mendeleev attempts to construct a periodic system, by far the most puzzling and least understood are those of the German-American chemist and polymath Gustavus Hinrichs. Hinrichs's first system, published in 1867 [1, 2], is summarized in a two-dimensional graph in which related elements (such as the halogens) are arranged on spokes radiating from a central point, elements with larger atomic weights being located farther from the center. In 1869, Hinrichs published two new charts of his system, in which the elements are arranged in tables rather than a graph [3–5].

Over the years [6–10], scholars have discussed Hinrichs's periodic systems[1] [11] and compared his achievements with those of others who proposed periodic systems in the 1860s, such as Alexandre-Émile Béguyer de Chancourtois (1820–1886), William Odling (1829–1921), John A. R. Newlands (1837–1898), Lothar Meyer (1830–1895), and of course Dmitri Mendeleev (1834–1907).[2] But many aspects of Hinrichs's periodic systems have remained puzzling even today.

In this paper, after a short biography of Hinrichs, I will offer some new insights into why Hinrichs constructed his periodic systems the way he did. Specifically, I will address the following questions:

- Are the dotted arcs in the 1867 chart circular or spiral?
- Why are the nitrogen and oxygen groups in the 1867 chart out of order?
- Why are the radial spokes in the 1867 chart located where they are?
- Why are the transition elements in the 1869 chart listed in reverse order and arranged in slanted columns?
- What are Hinrichs's ideas about how the periodic table gives insights into isomorphism, the relation between metals and non-metals, and atomic volumes?

7.2 Short Biography of Gustavus Detlef Hinrichs

Several articles [6, 8, 12], books [13, 14], and a thesis [15] give much information about Hinrichs's life and accomplishments; a list of his publications has also been compiled [16]. Many of Hinrichs's original publications, and documents about him, can be found today at the University of Iowa [17]. In addition, Hinrichs's personal papers are located at the University of Illinois, having been deposited there by one

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[1] I will refer to Hinrichs's classification schemes as "periodic systems" because the elements are arranged (mostly) according to increasing atomic weight, and elements with analogous properties are arranged in the same group. I use the word "mostly" in this definition because even modern periodic systems reverse the order of Ni and Co, and Te and I. For discussions of the definition of the term "periodic system" see [10] and [11].

[2] Other chapters in this volume contain discussions of the classification schemes of Béguyer de Chancourtois (5), Odling & Newlands (6), Meyer (8 and 9), and Dmitri Mendeleev (1).

of his grandsons between 1959 and 1964 [18]. Here I will briefly summarize some of the details available in these sources.

Gustavus Detlef Hinrichs (Figs. 7.1 and 7.2) was born on 2 December 1836 in the town of Lunden in the Holstein (i.e., southern) portion of the Jutland peninsula. Lunden was then part of Denmark but today is in Germany, about 50 km south of the Denmark-Germany border. He was the third of six sons of Johann Detlef Hinrichs (b. ca. 1802), a musician; Hinrichs's mother, Carolina Cathrina Elisabeth von Andersen (b. 4 October 1809), was the daughter of an artillery captain. In 1850, at the age of 13, Gustavus ran away from home to participate in the Schleswig-Holstein War, the unsuccessful first rebellion of ethnic Germans to achieve the secession of Holstein (and the adjacent state of Schleswig) from Denmark to the German Confederation. In July of that year, he took part in the battle at Idstedt as a uniformed drummer boy. He returned to Lunden in 1853 after hostilities ended, and shortly thereafter he enrolled in the Polytechnic School of the University of Copenhagen, where he completed the regular course of studies in 1856. He continued at the University for advanced work in mathematics, physics, and chemistry.

While at the University, Hinrichs earned money as a private instructor of students. In 1856 he wrote his first book, *Die electromagnetische Telegraphie*, and in 1860 he passed the exam at the University of Copenhagen for the *Candidatus mathematicus* degree,[3] equivalent to a master's degree. At Copenhagen, he had been particularly influenced by the Danish biologist Daniel Frederik Eschricht (1798–1863) and the meteorologist and geologist Johan Georg Forchhammer (1795–1865). In April 1861 he married Auguste Margaretha Friederike Springer (1839–1865), and in May–July 1861 he immigrated to the United States with his new wife, most likely to avoid service in the Danish military.

In 1861 Hinrichs settled in Davenport, Iowa,[4] where initially he taught high school. In 1862 he was appointed Professor of Modern Languages at the University of Iowa in Iowa City (he was fluent in Danish, French, German, Italian, and English, and knew some Greek and Latin), and in the next year he was appointed Professor of Natural Philosophy and Chemistry at that same institution, giving up his former title. Hinrichs's first wife died in 1865, leaving two children, and in July 1867 Hinrichs married Anna Catharina Springer (1842–1910; Auguste's younger sister) in Iowa City; presumably, Anna had come to America to care for Gustavus's children. With Anna, Hinrichs had two more children.

In 1875 Hinrichs founded the Iowa Weather and Crop Service [19, 20], and in 1886 he was dismissed from the University of Iowa (on trumped-up charges) [13, 15, 21]. In 1889 he was appointed Professor of Chemistry at St. Louis University, and he retired in 1907. He died 14 February 1923 in St. Louis (age 86).

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[3] In several papers Hinrichs published in 1860, this degree follows his name. Records at the University suggest that this certification may have been later invalidated [14].

[4] The Schleswig-Holstein Wars stimulated a large number of people to immigrate to Iowa. Gustavus's older brother, Carl Peter Hinrichs (1831–1894), a laborer, immigrated in 1868 with his wife Marie (1831–1916) to Clinton, Iowa, about 100 km from Iowa City.

Fig. 7.1 Gustavus Hinrichs in his middle years. *Left* photo courtesy of University of Iowa. *Right* photo from the *Souvenir and Annual*, 1881–1882

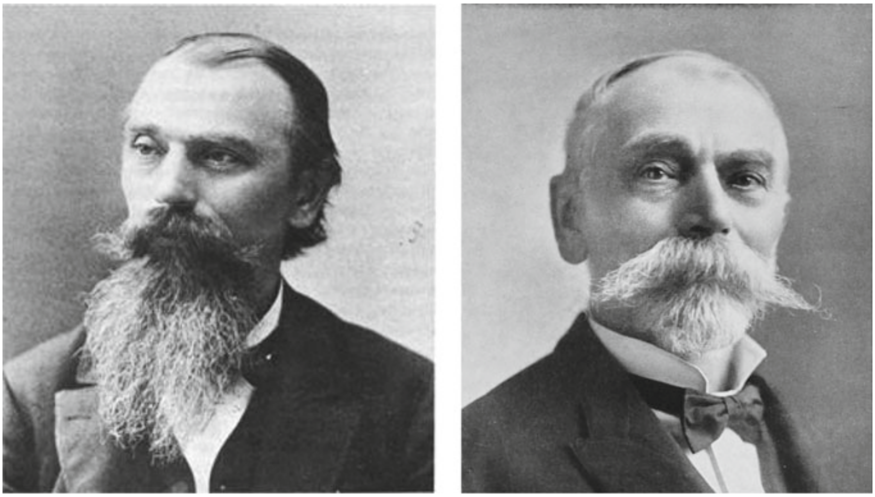

Fig. 7.2 Gustavus Hinrichs in his later years. Left: photo courtesy of University of Iowa. Right: photo from The Palimpsest, 1930

7.3 Hinrichs and Atomic Weights, 1866

Hinrichs published his first ideas about atomic weights in an 1866 article [22] in the *American Journal of Science* entitled, "On the Spectra and Composition of the Elements." Although much of this paper relates to finding regularities in the spectra of the elements (which has been discussed elsewhere [8]), I will instead focus on his ideas about the structure of atoms.

In this paper, Hinrichs states: "We suppose all elementary atoms to be built up of the atoms of *one single matter,* the *urstoff.…*" Hinrichs proposes that the atomic weight of hydrogen, referred to this prime element, is 4, but for the rest of the article he gives atomic weights relative to H = 1. He continues,

> the laws of mechanics force them [i.e., the particles of the urstoff] to arrange themselves regularly—and the most stable form will be the prism. If quite rectangular, and a, b, c be the number of primary atoms, in the three directions, we shall have [where A = atomic weight] …
>
> $A = a \cdot b \cdot c.$
>
> If the atom has a quadratic base, $a = b,$ we have
>
> $A = a^2 \cdot c.$
>
> If provided with one or several pyramidal additions, we have
>
> $A = a \cdot b \cdot c + k.$

Thus, Hinrichs clearly believed Prout's hypothesis [23–27] that all atomic weights are integer multiples of that of hydrogen (or a fraction thereof). As we will discuss below, Hinrichs makes no mention of the 1860 or 1865 publications of Jean-Servais Stas [28, 29] (1813–1891) discrediting Prout's hypothesis, or of the 1858 publications of Stanislao Cannizzaro [30, 31] (1826–1910) on atomic weights. Hinrichs mentions that he was using the atomic weights given in 1863 by Heinrich Will [32] (1812–1890), which for non-metals, the alkali metals, and the coinage metals mostly resembled the modern values, but for other elements were mostly one-half the modern values.

Examples of how Hinrichs tried to apply a common formula for the atomic weights of elements within groups are shown in Fig. 7.3. In attempting to fit the atomic weights of elements in a group to a common formula, Hinrichs was following efforts made in 1853 by the English chemist John H. Gladstone [33] (1827–1902), in 1854 by the American chemist Josiah Parsons Cooke [34][5] (1827–1894), in 1851 and 1858 by the French chemist Jean Baptiste André Dumas [35, 36] (1800–1884), and in 1860 by the American chemist Mathew Carey Lea [37] (1823–1897). All tried to fit the weights to formulas of the type $a + md$ (or to more complicated polynomial formulas), where a and d were numbers that were invariant within a group, and m was an integer that differed from element to element in that group. Only Hinrichs, however, proposed that the polynomial formulas reflected specific geometric (i.e., prismatic) arrangements of the basic building blocks.

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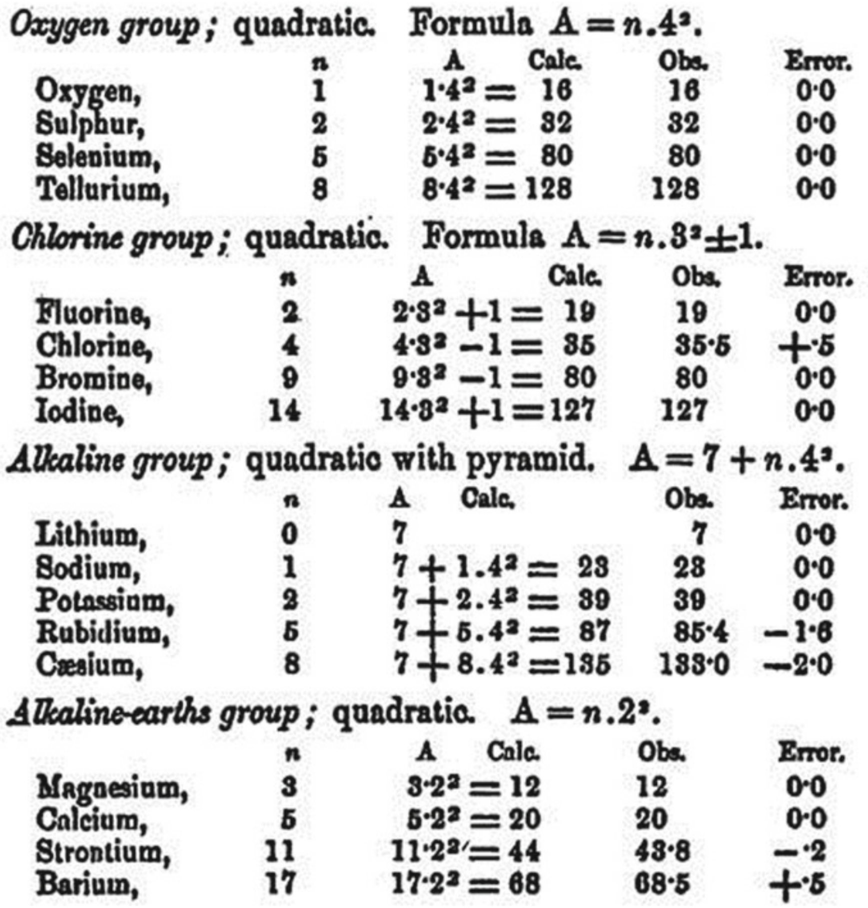
[5] See Chap. 1 in this volume for more on Cooke's work.



Oxygen group; quadratic. Formula $A = n.4^2$.

	n	A	Calc.	Obs.	Error.
Oxygen,	1	$1\cdot4^2 =$	16	16	0·0
Sulphur,	2	$2\cdot4^2 =$	32	32	0·0
Selenium,	5	$5\cdot4^2 =$	80	80	0·0
Tellurium,	8	$8\cdot4^2 =$	128	128	0·0

Chlorine group; quadratic. Formula $A = n.3^2 \pm 1$.

	n	A	Calc.	Obs.	Error.
Fluorine,	2	$2\cdot3^2 + 1 =$	19	19	0·0
Chlorine,	4	$4\cdot3^2 - 1 =$	35	35·5	+·5
Bromine,	9	$9\cdot3^2 - 1 =$	80	80	0·0
Iodine,	14	$14\cdot3^2 + 1 =$	127	127	0·0

Alkaline group; quadratic with pyramid. $A = 7 + n.4^2$.

	n	A	Calc.	Obs.	Error.
Lithium,	0	7		7	0·0
Sodium,	1	$7 + 1.4^2 =$	23	23	0·0
Potassium,	2	$7 + 2.4^2 =$	39	39	0·0
Rubidium,	5	$7 + 5.4^2 =$	87	85·4	−1·6
Cæsium,	8	$7 + 8.4^2 =$	135	133·0	−2·0

Alkaline-earths group; quadratic. $A = n.2^2$.

	n	A	Calc.	Obs.	Error.
Magnesium,	3	$3\cdot2^2 =$	12	12	0·0
Calcium,	5	$5\cdot2^2 =$	20	20	0·0
Strontium,	11	$11\cdot2^2 =$	44	43·8	−·2
Barium,	17	$17\cdot2^2 =$	68	68·5	+·5

Fig. 7.3 Table from Hinrichs's 1866 attempt to find numerical regularities in atomic weights [22]

Hinrichs mentions two of these predecessors in this 1866 paper [22]:

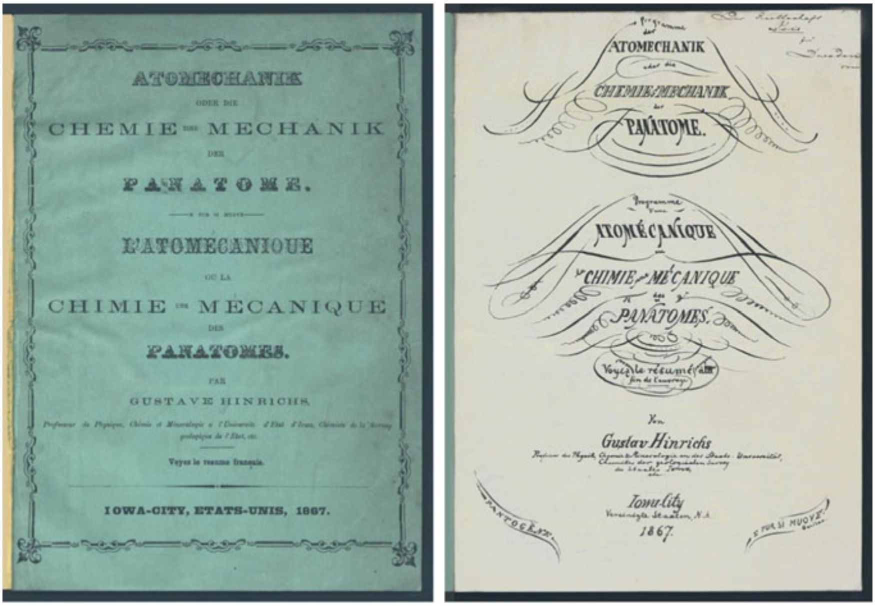
> We cannot here go into any detail as to the relation of these formulae to the numerical relations discovered by Carey Lea, Dumas and others; we hope soon to be enabled to publish our labors on the constitution of the elements. Neither can we here discuss these formulae in the sense of the mechanics of atoms, deducing the physical and chemical properties of the elements from these formula; these interesting relations also we must delay till some future, but I hope not a very distant, time.

Among Hinrichs's handwritten papers at the University of Illinois are two pages summarizing the polynomial formulas of Cooke and Dumas. We do not know whether Hinrichs had seen any of the classification schemes constructed between 1862 and 1864 by Béguyer de Chancourtois [38], Odling [39], Newlands [40], or Meyer [41].

7.4 Hinrichs and Atomechanics, 1867

One year later, in 1867, Hinrichs published an expanded version of his ideas about the inner structure of atoms, which he had briefly discussed in his 1866 paper. These new ideas appear in a privately lithographed reproduction of a 44 page handwritten treatise entitled *Programme der Atomechanik oder die Chemie eine Mechanik der Panatome* (Fig. 7.4; called *Programme* from here on). It is written entirely in German, except that copies not intended for Germany also include an abstract in French on pages 45–48. At the same time Hinrichs published a four-page English abstract of his *Programme* in the American periodical *Journal of Mining* [2]. The English abstract is not a straight translation of the French abstract.

A total of 112 copies of *Programme* were printed [42]. Hinrichs sent most of these to societies and universities, with only a few going to individuals. Among the latter were the Irish physicist John Tyndall (1820–1893), the German physicist and editor Johann Christian Poggendorff (1796–1877), the German chemists August Hofmann (1818–1892), Heinrich Will (1812–1890), Justus von Liebig (1803–1873), and Carl Remigius Fresenius (1818–1897), the German dictionary editor Felix Flügel (1820–1904), the London publisher of the *Mining Journal* Edward David Hearn (1832–1909), and the biologist Charles Darwin (1809–1882). He also sent copies to several geologists and mineralogists in Austria, Germany, and Russia: Hans Bruno Geinitz (1814–1900), Wilhelm Haidinger (1795–1871), Karl



ATOMECHANIK
ODER DIE
CHEMIE MECHANIK
DER
PANATOME.

L'ATOMECANIQUE
OU LA
CHIMIE MECANIQUE
DES
PANATOMES.
PAR
GUSTAVE HINRICHS

Voyez le resume français.

IOWA-CITY, ETATS-UNIS, 1867.

Programme
der
ATOMECHANIK
oder die
CHEMIE MECHANIK
der
PANATOME.

Programme
ATOMÉCANIQUE
CHIMIE MÉCANIQUE
PANATOMES.
Voyez le résumé
Von
Gustav Hinrichs
Iowa City
1867.

Fig. 7.4 Cover and title page of G. D. Hinrichs, *Programme der Atomechanik, oder die Chemie eine Mechanik der Panatome*, Iowa City (1867). Images courtesy of the University of Dresden

Friedrich August Rammelsberg (1813–1899), Carl Friedrich Naumann (1797–1873), Albrecht Schrauf (1837–1897), Aristides Brezina (1848–1909), and Nikolai Koksharov (1818–1893). In all, he sent 37 copies to Germany, 11 to the United States, 10 to France, 10 to England, 8 to Russia, 6 to Austria-Hungary, 6 to Scandinavia, 4 to Switzerland, 3 to Holland, 3 to Italy, 2 to Belgium, and 1 each to Greece, Portugal, and Spain [2]. His personal copy resides among the Hinrichs papers at the University of Illinois along with his hand-annotated list of recipients.

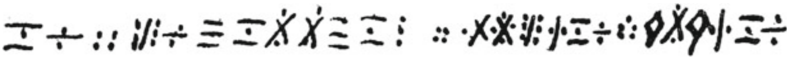
The lithographed text of the *Programme* is handwritten in English (or Latin) cursive, rather than the now-obsolete Kurrent script that was commonly used by German writers in the nineteenth century. Hinrichs's handwriting is relatively neat and mostly legible, although letters and words are sometimes sufficiently ill-formed that transcribing them involves guesswork (mit/mir/wir/wie are particularly vexing). In addition to the usual problems associated with distinguishing similarly-fashioned letters, long words at the ends of lines are often compacted and slanted downward to avoid the margin, and are frequently difficult to read as a result.

Hinrichs's *Programme* begins with a three-page historical forward (which states that the document was written between November 1866 and June 1867) and a short vocabulary list with definitions. The forward is followed by the main text of the *Programme*, which Hinrichs organizes into 400 numbered paragraphs. The main text is divided into an Introduction (paragraphs 1–5) and four main sections: Pantogen and the Elements (paragraphs 6–56), Chemical Characteristics of the Elements (paragraphs 57–120), Physical Characteristics (paragraphs 121–228), and Morphological Characteristics or Crystal Forms (paragraphs 229–399). The 400th paragraph contains some brief closing remarks. The text concludes with a colophon, which attests that the monograph was written personally by Gustavus Hinrichs and printed on stone by Augustus von Hageboeck, Lithographer in Davenport, Iowa. August Hageboeck (1836–1907) had immigrated to the United States from Germany in 1857.

In the following text, I will provide English translations of some key excerpts taken from Hinrichs's *Programme* (a transcription of original German text up through about paragraph 100, and an English translation thereof, can be found in the Appendix). I will focus on those portions of the *Programme* that are most relevant to Hinrichs's ideas on the classification of elements: i.e., the historical forward and the first two sections.

7.4.1 Historical Forward

The historical forward of the *Programme* begins with a chronology of the development of atomechanics, which Hinrichs says started with a document he had written in 1855, while still a student at Copenhagen. He states:

> I officially certified on the 7th of August a document in characters ("Zeichenschrift") entitled
>
> 
>
> containing the principles and some of the main conclusions already obtained. This document is also in my possession.

A 1969 article about Hinrichs [6] depicts this sentence in a figure bearing the caption: “The puzzling hieroglyphics in the [historical forward] of *Atomechanik*, referring to some secret ‘Zeichenschrift’ known only to the author.”

The shortness of the encoded text makes the cryptanalysis more difficult, but after a few blind alleys I solved the puzzle of the “hieroglyphics:” they are a simple substitution cipher in which the plaintext reads HINRICHSSCHE NATURPHILOSOPHI (*Hinrichs's Nature Philosophy*), the final “E” having been omitted.

There is no document with this title in the archive of Hinrichs's personal papers at the University of Illinois, but there is a 13-page handwritten document entitled *Atom-Mechanik*. On the cover of this document is an annotation by Hinrichs written in 1920: “Old document on Atom-Mechanics. June 15, 1868. The main part, in my own shorthand, is not dated, so far as I can see.” Most of the document is unreadable (at least to me): the words are written in a shorthand that resembles one for German writing introduced by Franz Xaver Gabelsberger (1789–1849) in 1834. If Hinrichs's dating from 50+ years after the fact is wrong, then this document may be the one in “Zeichenschrift” that the *Programme* says was written in 1855.

This 13-page manuscript, which mentions Pettenkofer, Dumas, and Prout (all of whom had written about atomic weights before 1855), contains some equations, such as $O = 32 = 2 \cdot 4^2 = 2 \cdot \square_2$, and $Mg = 48 = 3 \cdot 4^2 = 3 \cdot \square_2$, that suggest that Hinrichs is trying to rationalize (doubled) atomic weights on the basis of points arranged into geometric arrays such as squares. Loosely inserted into the document is a page showing a triangular grid, and calculations of the number of points in regular hexagons based on this grid.

Also in the Hinrichs archive at the University of Illinois (Box 3) are two longer handwritten documents, one entitled *Vorläufige Entwurf der Atomechanik* (*Preliminary Outline of Atomechanics*) that is undated but must have been written after April 1856 (the date of one of the articles Hinrichs cites), and the other entitled *Entwurf der Atomechanik* that is dated August and September 1858. The latter consists of 16 chapters, totaling 74 pages plus index.

Neither document contains any kind of periodic system. The earlier document does contain an inserted sheet, evidently added after the main text was written, summarizing an 1857 article [43] on the atomic weights of the elements by the German analytical chemist Heinrich Rose (1795–1864). Another inserted sheet, also bearing a reference to an article from 1857, gives atomic weights for 13 elements, all given on an $H = 2$ basis; these doubled atomic weights are based on a unit equal to half of a hydrogen atom.

The 1858 document contains an attempt to devise formulas for the (doubled) atomic weights of the elements, similar to the analysis he published eight years later in 1866. The logic behind the formulas, however, is far from clear: hydrogen $= 2 = 1^2 \cdot 2$, fluorine $= 38 = 3^2 \cdot 4 + 2$, chlorine $= 71 = 2^2 + 3^2 \cdot 7 + 2^2$, bromine $= 160 = 4^2 \cdot 10$, iodine $= 254 = 5^2 \cdot 10 + 2^2$, lithium $= 14 = 2^2 \cdot 3 + 2$, sodium $= 46 = 3^2 \cdot 5 + 1$; and potassium $= 78 = 3^2 \cdot 7 + 5$ [*sic*].

The earlier version of the *Entwurf* may be the one referred to in the next section of the *Programme*:

> 1856. In October of this year, I thought I was sufficiently advanced in my work to rewrite the publication. I ended up sending shorter reports to many of the existing men of science and also to some academies, expecting this to open up closer scientific communication. I had miscalculated in that. Passive resistance and the lack of help were to persuade me to further develop atomechanics.

The *Programme* then lists the scientific leaders Hinrichs had contacted in order to inform them of his ideas and to enlist their help in arranging for publication. The historical forward also describes the responses he received. Among those he contacted were Forchhammer (his former teacher), John Tyndall, J. C. Poggendorff (both mentioned above), the French editor Eugène d'Arnoult (fl. 1830s–1873; founder of *l'Institut, Journal Universel des Sciences*), the German chemist and physicist August Karl Krönig (1822–1879; known for his kinetic theory of gases, and then secretary of the Physical Society in Berlin), the Austrian mineralogist Wilhelm Haidinger (mentioned above; member of the Imperial Academy of Sciences in Vienna), the German physician and physicist Emil du Bois-Reymond (1818–1896), the Austrian chemist and mineralogist Anton Schrötter (1802–1875), the Danish-born German astronomer Peter Andreas Hansen (1795–1874), and the Prussian naturalist Alexander von Humboldt (1769–1859).

Although Hinrichs writes that he was grateful for the (mostly meager) responses he received, he accuses Krönig of plagiarizing some of his ideas in a monograph *Neues Verfahren zur Ableitung der Formel einer Verbindung aus den Gewichtmengen der Bestandtheile* (*New procedure for deriving the formula of a compound from the weights of the constituent parts*) [44]. On p. 53 of Krönig's monograph, as part of an eight-page section entitled "On the atomic weights of the elements," Krönig states: "As for the atomic weights I have assumed, I have used only Berzelius's numbers, taking into account the necessary corrections, based on half an atom of hydrogen as a unit…. So I set H = 2, O = 32, Cl = 71, and for example Ca = 80. Thus, all atomic weights appear as whole numbers." Krönig later refers to "the primordial particles, from which I think all bodies are composed, and of which 2 should form an atom of hydrogen, 32 an atom of oxygen, 71 an atom of chlorine, 80 an atom of calcium."[6]

In the historical forward to the *Programme*, Hinrichs implies that this "half-hydrogen" basis for atomic weights had been included in the reports that Hinrichs circulated privately beginning in late 1856. Hinrichs further quotes from a

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[6] "Was nun die von mir angenommenen Atomgewichte betrifft, so habe ich unter Berücksichtigung der nothwendigen Correktionen nur die Berzelius'schen Zahlen auf ein halbes Atom Wasserstoff als Einheit bezogen. Ich setze also H = 2, O = 32, Cl = 71, und noch beispielsweise Ca = 80. So erscheinen denn sämmtliche Atomgewichte als ganze Zahlen…. die Urtheilchen, aus denen ich mir alle Körper zusammengesetzt denke, und von denen 2 ein Atom Wasserstoff, 32 ein Atom Sauerstoff, 71 ein Atom Chlor, 80 ein Atom Calcium bilden sollen….".

letter he received back from Krönig dated April 15, 1857, in which Krönig said that he had read Hinrichs's report carefully and offered to circulate it to members of the Physical Society in Berlin who were part of Krönig's reading circle.

Even if we accept Hinrichs's implication that his circulated report contained his half-hydrogen hypothesis, it is perhaps forgivable if by 1866 Krönig had forgotten that he had first encountered the idea in a still-unpublished report sent to him nine years earlier by an obscure correspondent. Even more to the point, however, the idea that atomic weights are multiples of some fraction of a hydrogen atom had been proposed before 1856. The first to do so was Prout himself, in a letter sent on September 12, 1831 to the English chemist Charles Daubeny (1795–1867), and printed by Daubeny as an appendix in his textbook of that same year, *Introduction to the Atomic Theory* [45]. In his letter, Prout states that: "there seems to be no reason why bodies still lower in the scale than hydrogen … may not exist, of which other bodies may be multiples, without being actually multiples of the intermediate hydrogen."

In 1843, the Swiss chemist Jean Charles Marignac (1817–1894) was even more explicit [46]:

> In reality, so far, among all the bodies whose equivalent has been able to be determined with some precision, chlorine alone is obviously the exception. But still, by making a slight modification to Prout's law, this anomaly could be eliminated. It would suffice to admit that for some bodies, and chlorine would be in this case, the equivalent would be a multiple, not of the equivalent, but of the half-equivalent, of the hydrogen atom.[7]

In 1846, the French chemist Edme-Jules Maumené (1818–1898) promoted the same idea [47].

By 1867, however, almost all of the former advocates of Prout's hypothesis, even in such a modified form, had abandoned it. For example, Marignac, who had been the foremost skeptic of Stas's 1860 work [28] on atomic weights, was convinced by Stas's follow-up 1865 monograph [29]. That same year, in a review of the latter work, Marignac stated [48]:

> I can now no longer raise any doubts about the accuracy of the above numerical results, and I perfectly recognize with Mr. Stas that the atomic weights of bodies do not strictly offer among them the simple relationships that Prout's hypothesis would require.[8]

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[7] "En réalité, jusqu'ici, parmi tous les corps dont l'équivalent a pu être déterminé avec quelque précision, le chlore seul fait évidemment exception. Mais encore, en apportant à la loi de Prout une légère modification, on pourrait faire disparaître cette anomalie. Il suffirait d'admettre que pour quelques corps, et le chlore serait dans ce cas, l'équivalent serait un multiple, non plus de l'équivalent, mais du demi-équivalent, de l'atome d'hydrogène."

[8] "Je ne saurais plus maintenant élever aucun doute sur l'exactitude des résultats numériques qui précédent, et je reconnais parfaitement avec M. Stas que les poids atomiques des corps n'offrent point rigoureusement entre eux les rapports simples qu'exigerait l'hypothèse de Prout."

Hinrichs concludes the historical forward by mentioning his 1866 article in the *American Journal of Science*, and adds that in the Fall of 1866 he had come to an agreement with the editor-in-chief, James Dwight Dana (1813–1895), that Hinrichs's further work would be published in the same journal. But he adds, "I wanted to start with the crystallographic part, [and] work inductively to the pantogen…. Circumstances have caused the current publication."

The "circumstances" were a dispute with Dana; evidently, Hinrichs took offense at suggested changes in the manuscript that Dana and the referees suggested [12]. Hinrichs was later [49] to accuse Dana of plagiarizing his ideas in an 1867 article Dana wrote [50] on the relationship of crystalline form to chemical composition.

7.4.2 Introduction (§ 1–5) and Pantogen and the Elements (§ 6–35)

Beginning in Sect. 7.3, Hinrichs proposes that "everything of a material nature has arisen from a former substance. We may call this original element pantogen." He proposes that free pantogen "probably occurs in the outermost solar atmosphere (appears light-producing) and in the planetary nebulae. Hydrogen is closest to it. The relationship to the luminiferous ether remains undecided." But later in the *Programme* Hinrichs seems to use the word pantogen not only to mean this original form of matter, but also as matter as it exists today on the atomic scale.

Hinrichs continues by making the a priori assumption that atoms are composed of fundamental units which he calls pantatoms,[9] which mutually attract one another. The atomic weight of an atom is then proportional to the number of pantatoms it consists of. To account for the non-integral atomic weight of chlorine (35.5) when scaled to the atomic weight of a hydrogen atom, Hinrichs further assumes (unlike the assumption made in his 1866 paper) that the weight of a pantatom must be 0.5—i.e., half the atomic weight of hydrogen—so that, for example, there are 2 pantatoms in hydrogen, and 71 pantatoms in chlorine.

In paragraph 10, Hinrichs introduces his additional assumption that atoms consist of layers of pantatoms that are stacked to form prisms. He begins this proposal with the statement:

> There are only two possible compound arrangements in a plane for equal material points: at the corners of an equilateral triangle or a square. Accordingly, there are two kinds of pantogen compounds or elements; namely trigonoids and tetragonoids.

Hinrichs then discusses various ways to arrange pantatoms into plates based on triangular and square grids. He begins by depicting and counting the number of pantatoms included in plates based on triangular grids having equal-length sides (Fig. 7.5, parts a–i): for six-sided plates (i.e., regular hexagons) the numbers are 1, 7, 19, … and for four-sided plates (i.e., diamond shapes) the numbers are 4, 9, 16,

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[9] Although Hinrichs uses the spelling "panatom" in the title of his monograph, he uses this spelling throughout the main text.

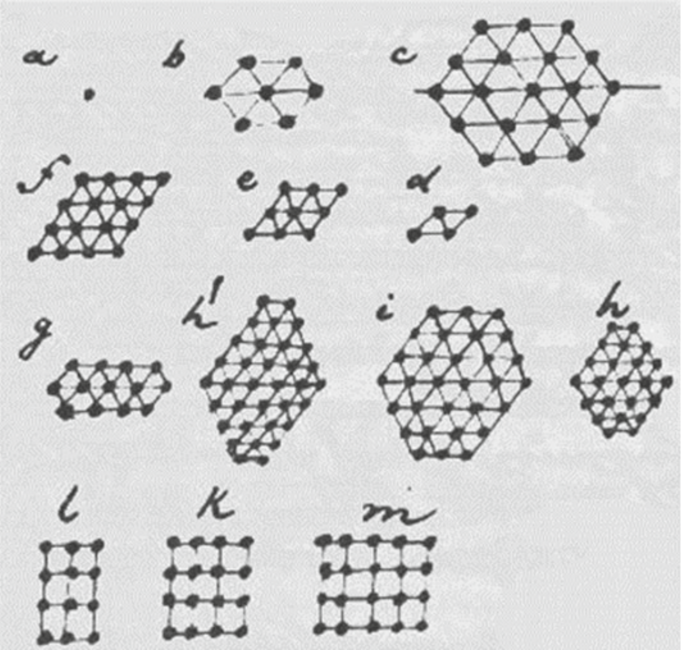

Fig. 7.5 Various rafts or layers of pantatoms from paragraph 11 of *Programme der Atomechanik*

…. But he also analyzes certain irregular hexagons with unequal-length sides (examples include those with 13, 23, 30, and 34 pantatoms).

For the plates based on square grids (Fig. 7.5, parts k–m), Hinrichs mentions both plates with equal-length sides (i.e., squares), as well as rectangular plates having unequal sides (examples include those with 12, 16, and 20 pantatoms). Hinrichs does not mention the fact that the four-sided plates based on triangular grids (Fig. 7.5, parts d–f) are slanted versions of (with the same number of total points as) square plates with the same length side: e.g., a plate with 4, 9, or 16 points can be represented either way. This is just one of the many degrees of freedom in Hinrichs's system.

Hinrichs then suggests that "by placing these pantatom plates vertically above one another, prisms emerge as the atoms of the elements." The number of pantatoms in the base of the prism he calls the atomare (symbol a), and the number of layers—i.e., the height of the prism—he calls the atometer (symbol m). Therefore, "if there is only one prism, then the sum total of the pantatoms in the element atom or the atomic weight = atogram $g = m \cdot a$".

Hinrichs proposes a Linnean nomenclature (order, genus, species, variety) for classifying elements:

> [the elements] divide into 2 orders (the trigonoids and the tetragonoids) according to the mutual association of the pantatoms on average. This order divides into genera according to the external form of the figure…. The species (the element) is determined by the atometer *m*. Varieties (very closely related elements [having] nearly the same atomic weight) are created by merging the subsequently determined caps onto the prism.

Hinrichs's orders divide all the elements into two large categories (see below); his genera are the equivalent of our groups (alkali metals, halogens, etc.); his species are the elements within a group. In allowing for varieties, Hinrichs acknowledges that pure prismatic structures cannot be assigned for some atoms; it is sometimes necessary to add caps ("Aufsätze") of additional pantatoms.

Hinrichs says shortly thereafter that trigonoids are metalloids (what we would call non-metals) and tetragonoids are metals. Thus, fluorine, oxygen, and nitrogen (along with their heavier congeners) are trigonoids, whereas all other elements are tetragonoids.[10] Hinrichs evidently made this choice (rather than the reverse) because he believed it led to a more consistent set of pantatomic structures for the various atoms, and thus a more consistent classification scheme. Of course, Hinrichs's proposal that there was any such correlation was another of his a priori assumptions.

A key assumption in Hinrichs's system is that atoms of elements that belong together in a group have similarly shaped prismatic structures with the same base: "Thus the general character of the element will be determined by *a*, while the particular determination of this character will be expressed by *m*, the height".

Based on this assumption, Hinrichs fits the atograms (i.e., twice the atomic weights) of the elements within a group to a common formula, much like he had done in his 1866 paper, except now the formulas correspond to stacks of plates based on triangular or square grids (rather than square grids only), and the basic unit has an atomic weight of ½ rather than ¼ or 1 on a H = 1 scale. Examples of some of his proposed arrangements of pantatoms are as follows (see Fig. 7.6):

- H (2) = 2 layers of 1 pantatom
- F (36) = 5 layers of 7-pantatom hexagons +1
- N (28) = 4 layers of 7-pantatom hexagons
- O (32) = 8 layers of 4-pantatom double triangles (diamonds)
- K (78) = 2 layers of 7-pantatom hexagons + 4 layers of 4 × 4 squares
- Ca (80) = 2 layers of 4 × 4 squares + 2 layers of 4 × 6 rectangles.

From the fact that Hinrichs proposes that calcium is composed of 80 pantatoms, it is apparent that in the year between 1866 and 1867 he has switched over entirely to the system of atomic weights advocated by Cannizzaro and others.

Note that the most straightforward proposal for the structure of calcium would be five layers of 4 × 4 squares, but instead Hinrichs proposes a more complicated

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[10] Hinrichs's categorization of metals and non-metals is different from ours, and from that of most of his contemporaries. For example, he placed carbon and boron among the metals, and antimony and tellurium among the nonmetals.

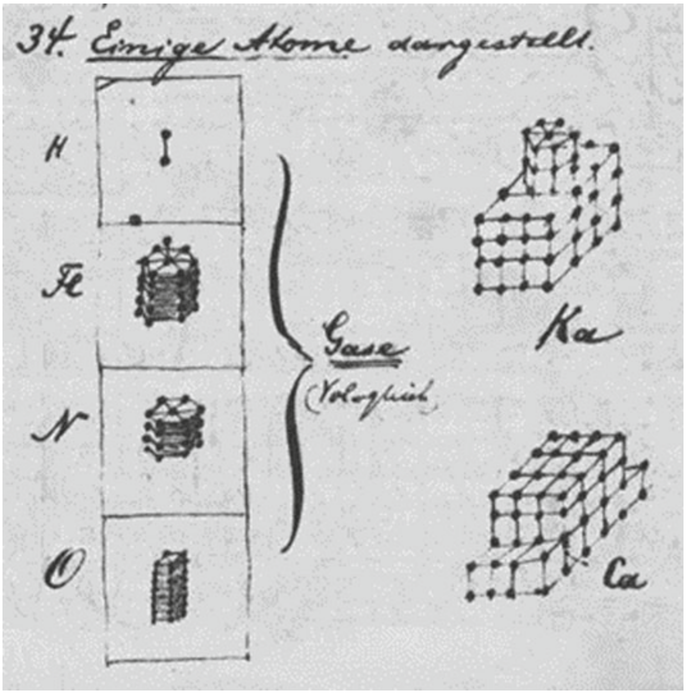

Fig. 7.6 Atoms as stacks of pantatom layers, from paragraph 34 of *Programme der Atomechanik*

structure involving the stacking of both square and rectangular plates (Fig. 7.6). He does this in order to devise a formula that also applies to the congeners of calcium: strontium and barium. Also, despite Hinrichs's proposal that metals are tetragonoids, he proposes that potassium (Ka), along with the other alkali metals, consists of hexagon-shaped triangular plates on top of square plates. We will return to this point later.

This section of Hinrichs's monograph contains a series of 13 tables, one for each of his different groups of elements: the pantoids (containing only hydrogen), the chloroids (halogens), phosphoids (pnictogens[11]), sulphoids (chalcogens), kaloids (alkali metals through Rb and perhaps also including In, Cs, and Tl), calcoids (heavier alkaline earths starting with Ca), kadmoids (Mg, Zn, Cd, and Pb), ferroids (Al, Fe, Rh, Ir), molybdoids (Cr, Mo, V, W), cuproids (Cu, Ag, Au),[12] titanoids (C, Si, Ti, Pd, Pt, and perhaps also including Zr, Sn, Ta, and Th), sideroids (Cr, Mn, Fe Ni, Co, and U), and "undetermined" (B, Be, Hg). Chromium and iron each appear in two of these groups. Hinrichs also mentions but does not give formulas

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[11] For convenience, I use here a modern term for the nitrogen group [51].

[12] Hinrichs was the second person to place copper, silver, and gold into the same group within the context of a periodic system; this had first been done in 1864 by Lothar Meyer.

for two additional groups, rhodoids (Rh, Ru) and iridoids (Ir, Os), claiming that too little is known about their atograms (i.e., atomic weights). In fact, this is not correct: accurate atomic weights for these elements had been reported for Ru in 1845 by the Russian chemist (and discoverer of Ru) Carl Ernst Claus [52] (1796–1864) and for the other three elements in 1828 by the Swedish chemist Jöns Jacob Berzelius [53] (1779–1848).

Each of the 13 tables contains a general parameterized formula for the atogram (i.e., twice the atomic weight), along with the values of parameters in the formula that correspond to each element. For example, the table for the chloroids (i.e., halogens), the general formula is $(1) + m\cdot(p)$, where (p) denotes a six-sided raft (not necessarily with equal sides) containing p pantatoms arranged in a triangular grid. Fluorine has $m = 5$ and $p = 7$, chlorine has $m = 10$ and $p = 7$, bromine has $m = 12$ and $p = 13$, and iodine has $m = 11$ and $p = 23$. The “predicted” atomic weights for fluorine and bromine show a discrepancy of 1.0 and 1.5, respectively, with respect to the then-accepted values.

Although Hinrichs states that elements in the same group have similar shapes with the same base, the table for the halogens shows that his “atomic structures” conform to a looser rule: elements in the same group are represented by the same formula, but the base can change from, for example, a regular hexagon of 7 or 13 pantatoms to a six-sided (but not regular) plate of 23 pantatoms.

The formulas for the atograms of all 13 groups of elements according to Hinrichs’s classification scheme can be found in Table 7.1.

Table 7.1 Hinrichs’s formulas for the atograms (i.e., doubled atomic weights) of the elements[a]

Pantoids (H)	$m\cdot(1)$
Chloroids (F, Cl, Br, I)	$(1) + m\cdot(p)$
Phosphoids (N, P, As, Sb, Bi)	$m\cdot(p)$
Sulphoids (O, S, Se, Te)	$m\cdot/p^2/ = \mu\cdot[2p^2]$
Kaloids (Li, Na, K, In, Rb, Cs, Tl)	$2(7) + 2\cdot m\cdot 4^2$
Calcoids (Ca, Sr, Ba)	$2\cdot 4^2 + m\cdot 2\cdot[4\cdot 6]$
Kadmoids (Mg, Zn, Cd, Pb)	$2\cdot 4^2 + m\cdot 2\cdot[4.6]$ or $2\cdot 4^2 + \mu\cdot[8\cdot 12]$
Ferroids (Al, Fe, Rh, Ir)	$K + m\cdot 2\cdot[3\cdot 4]$ m even
Molybdoids (Mo, V, W)	$K + m\cdot 2\cdot[3\cdot 4]$ m odd
Cuproids (Cu, Ag, Au)	$K + m\cdot[5\cdot 8]$
Titanoids (C, Si, Ti, Pd, Pt)	$2\cdot[3\cdot 4] + m\cdot[4\cdot 5]$
Sideroids (Cr, Mn, Fe, Ni, Co, U)	$K + 4\cdot 2\cdot[3\cdot 4]$
Undetermined (B, Be, Hg)	

[a] In this table, (p) denotes a six-sided triangular raft containing p pantatoms, $/p^2/$ denotes a square raft with sides of length p, and $[i\cdot j]$ denotes a rectangular raft with sides of length i and j. The variables m and K represent integers, and $\mu = m/2$; although Hinrichs does not say so, K seems to be restricted to either 7 or a multiple of 4

7.4.3 Hinrichs's Chart of 1867 (§ 36–56)

In paragraph 37 of the *Programme*, the chart shown in Fig. 7.7 appears. Hinrichs introduces his chart as follows:

> To illustrate the mechanical or rational classification of the elements contained in the foregoing [tables], I present them in the following drawing. The pantogen forms the midpoint, the genera are represented by rays from this point, and the species are recorded in these rays where the distance from the center equals the atogram *g* ….

Because the distance from the center is the atogram (=twice the atomic weight), the dotted lines in Hinrichs's diagram have usually been referred to as a spiral [6, 8, 9, 54]. But such a description is actually only half-true. In (unnumbered) paragraph 54, Hinrichs states explicitly that the dotted lines in his diagram form a spiral, but with a twist:

> …the known elements in our chart follow one another in spiral lines. See in 37 [i.e., his chart] the lines H-Li-C-O-N-Fl-Na–Mg-Al–Si-S-P-Cl-Ka-Ca–Ti and then in the opposite direction Ti–Fe-Zn-In-Br-As-Se-Pd-Rh-Cd-Cs-Jo-Sb-Te.

The words *and then in the opposite direction* ("in entgegengesetzte Richtung") indicate that Hinrichs considered that the elements form *two* spirals, not one (Fig. 7.8). Elements from H to Ti lie on a *clockwise* spiral, but from Ti through Te

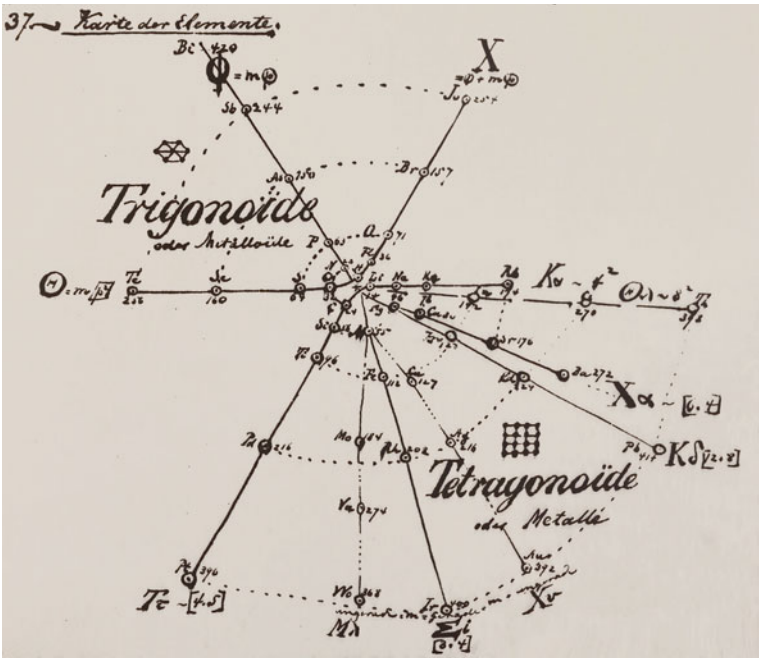

Fig. 7.7 Hinrichs's 1867 chart of the elements from paragraph 37 of his *Programme der Atomechanik*. Image courtesy of the University of Dresden

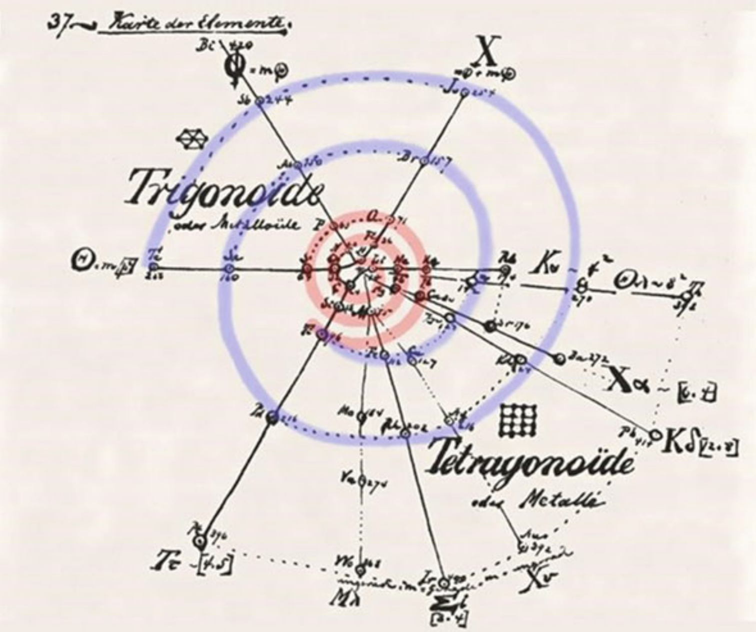

Fig. 7.8 Hinrichs's chart, in which two spirals have been added as described in unnumbered paragraph 54 of *Atomechanics*, the inner spiral proceeding clockwise, the outer one counterclockwise, with the change in direction occurring at titanium

the spiral proceeds *counterclockwise*. The change in direction of the spiral upon reaching titanium can be understood by reference to the modern periodic table: titanium is the first of the d-block transition elements. Hinrichs knew that the next elements after titanium in order of increasing atomic weights were all metals, and he concludes that the spiral must reverse direction in order to place these succeeding transition elements within his tetragonoid sector.

The elements Rb, Sr, Ba, and Mo are skipped in Hinrichs's sequence, and indeed they do not fall on the dotted lines in the chart; Hinrichs makes no comment on these omissions. The heaviest elements, Pt, W, Ir, Au, Pb, and Tl, are placed on their own dotted line; Hinrichs does not say in which direction he intended this portion of the curve to spiral, and it seems likely that he couldn't decide. Cu and Ag are also omitted from the list, even though these element do lie on the dotted lines.

A key feature of any classification of the elements that can be called periodic is the recognition that the similarities of the elements have a two-dimensional character: not only do the properties of elements vary regularly *within* a group,[13]

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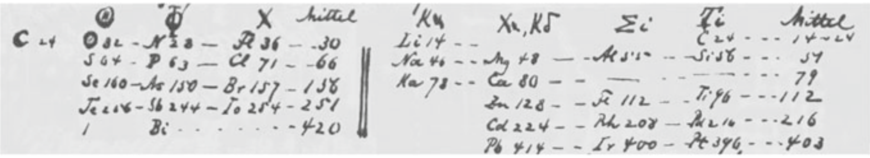
[13] As first pointed out for atomic weights by Johann Döbereiner (1780–1849) some 50 years previously. But non-quantitative chemical similarities (such as found, for example, in the compounds of Sr and Ba, and in the hydrohalic acids of F and Cl) had been recognized in the late 1700s.



	Θ	Φ	X	Mittel	Kα	Xα, Kδ	Σι	Tτ	Mittel
C 24	O 32	N 28	Fl 36	30	Li 14			C 24	14-24
	S 64	P 63	Cl 71	66	Na 46	Mg 48	Al 55	Si 56	51
	Se 160	As 150	Br 157	156	Ka 78	Ca 80			79
	Te 256	Sb 244	Io 254	251		Zn 128	Fe 112	Ti 96	112
		Bi		420		Cd 224	Rh 208	Pd 216	216
						Pb 414	Ir 400	Pt 396	403

Fig. 7.9 Table showing inter-group relationships of Hinrichs's doubled atomic weights.[14] From paragraph 53 in Hinrichs's *Programme der Atomechanik*

there are regularities that relate *different* groups (which Hinrichs called genera). Hinrichs recognizes this two-dimensional character in paragraph 53: "…nearly equal values of *g* [i.e., Hinrichs's atogram] can correspond to different forms; that is, near equal *g* give species of different genera. Our chart § 37 shows this quite clearly." This sentence is followed by a table (Fig. 7.9) that emphasizes recurrent similarities in the atomic weights of elements from different genera.

Thus, the elements O–N–F all have atograms near 30, the heavier congeners S–P–Cl all have atograms near 66, and so on for the subsequent members of those three groups. Similarly, Hinrichs points out that the elements Na–Mg–Al–Si all have atograms near 51, although the heavier congeners show quite a bit more scatter, in part because some of the elements Hinrichs includes are today recognized as belonging to other groups.

The table in Fig. 7.9 is significant because, as a (partial) tabular representation of Hinrichs's periodic system, it more closely resembles other periodic systems devised in the 1860s, and thus makes comparisons a little easier. This table includes all three of the trigonoid groups, but only four of the tetragonoid groups. The latter include the alkali metal groups and the three tetragonoid groups which Hinrichs calls in paragraph 49 "the 3 main genera with a rectangular base, namely the ferroids, … the titanoids …, and the kadmoids …." We will return to this idea of there being a smaller number of "main" tetragonoids below.

Two further aspects of Hinrichs's chart deserve comment: the first is why the halogens, chalcogens, and pnictogens (Hinrichs's X, Θ, and Φ groups, respectively)

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[14] Hinrichs sometimes uses Tτ and sometimes (as here) Tι to denote the titanoid group; for clarity, I use only Tτ.

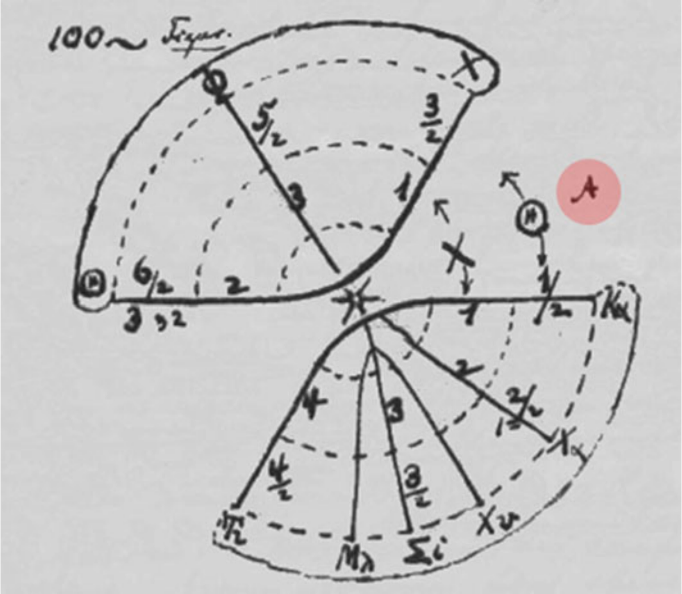

Fig. 7.10 Diagram showing the combining ratios of elements with hydrogen and the halogens (*inner circle*) and with the chalcogens (*outer circle*). A circle has been added to emphasize what Hinrichs calls "point A". From paragraph 100 in *Programme der Atomechanik*

are out of order when compared with the modern table, and the second is why the spokes appear where they do (i.e., what is the basis for their angular positions). The first of these aspects has long been noted [8] but never explained.

The reason Hinrichs chose the order chalcogens–pnictogens–halogens (i.e., O–N–F) rather than pnictogens–chalcogens–halogens (N–O–F) can be deduced from a diagram he gives in paragraph 100 (Fig. 7.10). This diagram, which appears in the next section on the chemical properties of the elements, immediately follows a summary of combining ratios with hydrogen and the halogens.

In reference to this diagram, Hinrichs states,

> In the adjacent figure, the main result of the compound ratios is compiled. The number indicates how many atoms of X (inner circle) or Θ (outer) unite with one atom of the different genera (their symbol in the outermost circle) to [give] the main compound.[15] One can see that the ratio in both the X [i.e., halide] and the Θ [i.e., chalcogenide] compounds grows regularly from [point] A in every direction, reaching its maximum at Θ [O-S-Se-Te group] among the trigonoids [and] at Tτ [C-Si–Ti-Pd-Pt group] among the tetragonoids.

Point A in Hinrichs's diagram occupies a place that today would be filled with the noble gases, which have a characteristic combining ratio of zero. Starting from this location, Hinrichs places the groups of elements in order of increasing

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[15] "Hauptverbindung".

combining ratios. Indeed, if one moves column by column away from the lighter noble gases in the modern periodic table, the valence of E in the EH_n hydrides increases in the order 1, 2, 3, 4… in both directions (i.e., increasing and decreasing atomic number).

Hinrichs had previously stated in paragraphs 92 and 95–98 that the various groups have combining ratios with the chloroids (X) as follows: XX for F and its congeners, ΘX_2 for O and its congeners, and ΦX_3 for N and its congeners (these are the trigonoid groups), and $T\tau X_4$ for C and its congeners, $\Sigma\iota X_2$, $\Sigma\iota X_3$, or $\Sigma\iota X_4$ for Al and its congeners, $X\alpha X_2$ for Mg and its congeners, and $K\alpha X$ for Li and its congeners (these are the tetragonoid groups listed in his table in paragraph 53; Fig. 7.9). In the diagram in paragraph 100, Hinrichs chose $\Sigma\iota X_3$ as the "main" composition of the group of elements headed by Al. Had Hinrichs based his chart on these trends in combining ratios, he would have placed the F, O, and N groups in the correct order.

Instead, Hinrichs evidently places greater weight on the combining ratios with chalcogens (oxygen in particular). In the 1860s [55], the highest known chlorine oxide was Cl_2O_3; although I_2O_5 and I_2O_7 had been claimed, the evidence in support of these higher oxides was ambiguous (and even today the existence of I_2O_7 is doubtful).[16] Thus, Hinrichs mentions that F and its congeners form binary compounds whose maximum chalcogen content is embodied in the formula $X_2\Theta_3$, whereas N and its congeners form binary compounds up to $\Phi_2\Theta_5$ (such as P_2O_5 and As_2O_5), and among O and its congeners the compounds SO_3 and SeO_3 exist. Correspondingly, in his diagram, Hinrichs arranges the F–N–O groups in order of increasing (maximum) combining ratio with oxygen: 3/2, 5/2, and 6/2.

Thus, it is clear that, to Hinrichs, atomic weights play an important role in determining what elements belong together in the same groups, but they play a lesser role in determining how the groups are ordered with respect to one another. Hinrichs focuses more on the *similarity* of the atomic weights of elements from different groups, and less on arranging them in strict order of increasing atomic weight. Instead, Hinrichs places greater importance on combining ratios when deciding on the relative arrangement of the groups in his periodic system.

Almost all of Hinrichs's atomic weights are close to the modern values but, like everyone else in the 1860s, he used wildly incorrect atomic weights for vanadium, tantalum, and uranium (137, 137.6, and 120, respectively, vs. modern values of 51, 181, and 238). Of these, only vanadium appears in his chart, and not surprisingly this element is located farthest from any of the arcs of his spiral. It is interesting that this deviation did not prompt Hinrichs to consider whether his assigned atomic weight of vanadium might be wrong.

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[16] In paragraph 67 of the *Programme*, Hinrichs mentions Cl_2O_5 and Cl_2O_7 as example molecules, but in 1867 these two substances had never been prepared, although analogous chlorate and perchlorate salts (and the corresponding acids) were known.

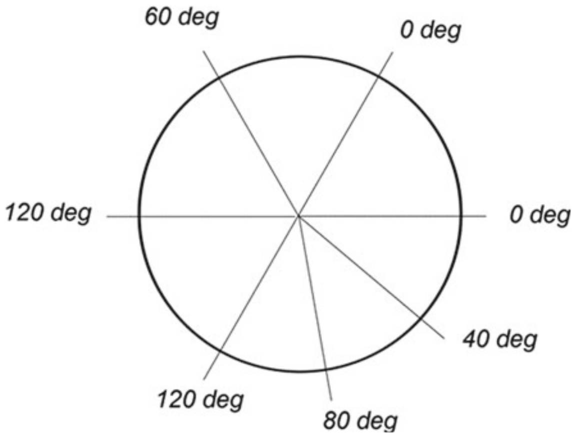

Fig. 7.11 Possible structure of Hinrichs's chart. Compare with Fig. 7.10

As to the second aspect of Hinrichs's chart, i.e., the basis for the angular positions of the various spokes, Hinrichs says nothing in the *Programme*.[17] But the diagram in paragraph 100 also helps explain why the spokes are where they are.

Evidently, Hinrichs intended the trigonoids collectively to subtend approximately 120° of arc, and the same for the tetragonoids; he places these two arcs symmetrically within a circle, separated by 60° (Fig. 7.11). Hinrichs chose the alkali metal and chalcogen spokes to define the horizontal axis of his chart. He does not give reason for this arrangement, but one possibility is that Hinrichs orients the spokes in this way so that the maximum valence (as given by the outermost values in Fig. 7.10) increases from right to left.

Hinrichs considers the molybdoids Mλ (Cr, Mo, V, W) and the cuproids Xυ (coinage metals) as subordinate to the ferroids Σι (Al, Fe, Rh, Ir): in paragraph 47 he states "the molybdenoids and cuproids are … only side branches of the ferroids." This subordinate role is reflected in his omission of the molybdenoids and cuproids from his list of the "main" tetragonoids, as given in the table in paragraph 53 (Fig. 7.9), and also in his construction of the chart. Thus, the spokes for the three trigonoid groups and the four "main" tetragonoids are spaced equally, by 60° of arc for the trigonoids, and 40° for the tetragonoids. The subordinate molybdoids and cuproids lie on partial spokes that flank the spoke for the ferroids.

Hinrichs justifies his designation of the molybdenoids and cuproids as side branches because their atograms can be represented by formulas of the type $a + md$ where m is odd, whereas the ferroids have formulas $a + md$ where m is even. The flanking relationship of the molyboids and cuproids is evident in Hinrichs's chart in

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[17] In his 1867 abstract published in the *Journal of Mining*, Hinrichs says, "The most convenient representation of this classification is obtained by representing each genus by a line radiating from the centre … the trigonoids upwards and to the left, the others downward and to the right." But this sentence is merely descriptive, not explanatory. Interestingly, in 1894 Hinrichs added, "My original conception was the arrangement on a right cone with π at the vertex. This brings the genera less far apart for the high atomic weight, but cannot be readily reproduced" [56, p. 241]. Here, π is Hinrichs's symbol for pantogen, which is placed at the very center of the diagram.

paragraph 37: these flanking spokes are labeled "*m* = ungerade (odd)" whereas the ferroid spoke is labeled "*m* = gerade (even)".

We can speculate that, because vanadium was on one of these flanking partial spokes, it was of less concern to Hinrichs that this element did not lie on any of the dotted spiral lines. But Hinrichs is silent as to the reasons that Rb, Sr, and Ba also do not lie on his dotted lines.

7.4.4 Chemical Characteristics (§ 57–110)

The next section of the *Programme* deals with the chemical characteristics of the elements. He begins with a statement about chemical bonding: "The chemical bonding between two atoms A and B, viewed as a mechanical phenomenon, can only consist of the side-by-side arrangement (juxtaposition) of atoms, AB." He then devotes a lengthy discussion to the geometries of molecules (three-atom molecules are triangles, etc.) and to the contraction in volume that occurs when, for example, hydrogen and oxygen gases react to form water.

Hinrichs then tries to explain the atomicities (i.e., valences) of the atoms in terms the pantatomic structures he has assigned. The following is taken from his English abstract [2]:

> I. One atom of any *chloroid* combines with one of hydrogen; for (1)+*m*(*p*) shows one prominent centre of attraction.
> II. One atom of a *sulphoid* is saturated by two atoms of H: for the atomare[18] 2 2^2 of O shows two equal centres of attraction.
> III. One atom of any *phosphoid* requires three atoms of H for saturation; for the regular hexagon gives as foci the centre of gravity of the three rhombs into which it is divisible.

Thus, Hinrichs proposes that the halogens have pantatomic structures in which the single capping pantatom is responsible for the valence of one, the divalent chalcogens have structures that consist of two identical halves, and the trivalent pnictogens have structures based on hexagons, which can be considered as consisting of three joined rhombuses. Here is another example of Hinrichs formulating ad hoc hypotheses, which in this case are not even internally consistent.

Hinrichs's "explanations" of gas volume changes in chemical reactions and interatomic bonding are outside of the scope of the present discussion. Those interested in these aspects of Hinrichs's theories are encouraged to consult the appendix to the present article.

I will, however, mention one aspect of Hinrichs's theory of atomic structure, which as far as I am aware has not been pointed out previously. This is Hinrichs's explanation of the cause of isomorphism.

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[18] Hinrichs has evidently made a mistake here; presumably he intended to say that the atomare is 2^2.

89. Ammonium, dargestellt und mit Kalium verglichen. —

Fig. 7.12 Hinrichs's explanation of the isomorphism of ammonium and potassium salts. From paragraph 89 of *Programme der Atomechanik*

90. Cyan dargestellt und mit den Chloroiden verglichen.

Fig. 7.13 Hinrichs's explanation of the isomorphism of cyanide and chloride salts. From paragraph 90 of *Programme der Atomechanik*

Hinrichs proposes that, in the ammonium ion (NH_4^+), the N atom (4 layers of 7-pantatom hexagons) is attached to four H atoms (each consisting of 2 pantatoms), which he places below the N atom as four "legs" that define a square-based parallelepiped (the overall shape is reminiscent of NASA's lunar module). His model for potassium (shown in his paragraph 34; Fig. 7.6) consists of 2 layers of 7-pantatom hexagons on top of 4 layers of 4 × 4 squares. Therefore, according to Hinrichs, ammonium and potassium commonly form isomorphous compounds because these chemical species have about the same three-dimensional shape (Fig. 7.12).

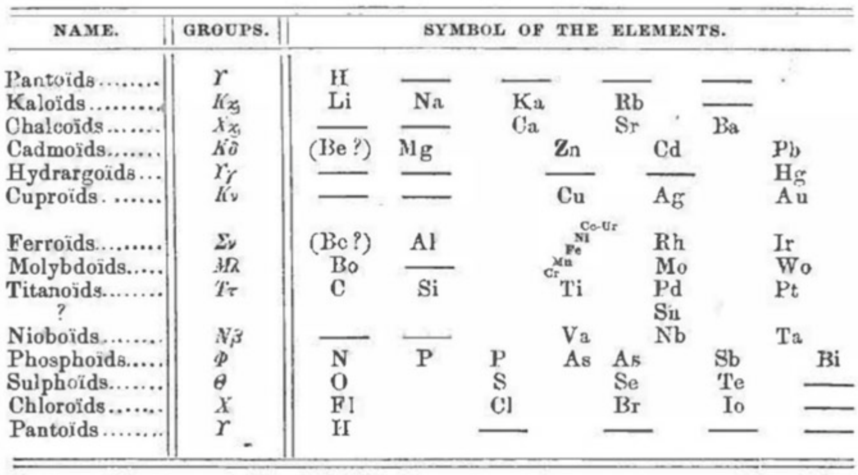
Similarly, cyanide and chlorine also form many isomorphous compounds, and Hinrichs accounts for this phenomenon in a similar way (Fig. 7.13). The cyanide ion he depicts as a nitrogen atom on top of a carbon atom; the height and cross section of the resulting shape are similar to those of his proposed structure of chlorine (10 layers of 7-pantatom hexagons plus 1).

Hinrichs evidently kept the phenomenon of isomorphism in mind as he made his choices for the arrangements of pantatoms within atoms. Although he would have disagreed strongly with the comparison,[19] this part of Hinrichs's *Programme* is similar in intent to the work of the French chemist and crystallographer Marc Antoine Gaudin (1804–1880), who devoted his life (unsuccessfully) to working out the arrangements of atoms within molecules and molecules within crystals [57, 58].

7.4.5 Physical Characteristics (§ 121–228), and Morphological Characteristics or Crystal Forms (§ 229–399)

The last two sections of the *Programme* contain detailed discussions of trends and mathematical relationships between chemical formulas and various properties of the elements, such as specific weights (i.e., densities), specific heats, melting points, boiling points, refraction equivalents (i.e., the refractive index minus unity, divided by the density and multiplied by the atomic weight), spectral lines, and the axial ratios, external forms, and optical properties of crystals. In a few cases, Hinrichs notes regular trends in these properties as a function of increasing atogram (atomic weight): for example, he mentions that the melting points of Li, Na, and K decrease in that order. But other than a few scattered examples, Hinrichs is silent on the relationship of these properties to his periodic system.

Hinrichs also published his ideas on these topics in two contemporary summaries [2, 59].



NAME.	GROUPS.	SYMBOL OF THE ELEMENTS.								
Pantoïds........	Υ	H	——	——		——		——		
Kaloïds.........	Kϰ	Li	Na	Ka		Rb		——		
Chalcoïds........	Xϰ	——	——	Ca		Sr		Ba		
Cadmoïds.......	Kδ	(Be ?)	Mg		Zn		Cd		Pb	
Hydrargoïds...	Υγ	——	——		——		——		Hg	
Cuproïds.	Kν	——	——		Cu		Ag		Au	
Ferroïds.........	Σν	(Bc ?)	Al		Co-Ur Ni Fe		Rh		Ir	
Molybdoïds.....	Mλ	Bo	——		Mn Cr		Mo		Wo	
Titanoïds........	Tτ	C	Si		Ti		Pd		Pt	
?							Sn			
Nioboïds........	Nβ	——	——		Va		Nb		Ta	
Phosphoïds.....	Φ	N	P	P	As	As		Sb		Bi
Sulphoïds.......	θ	O		S		Se		Te		——
Chloroïds.......	X	Fl		Cl		Br		Io		——
Pantoïds........	Υ	H		——		——		——		——

Fig. 7.14 Hinrichs's chart from *The Pharmacist* (1869) [3]

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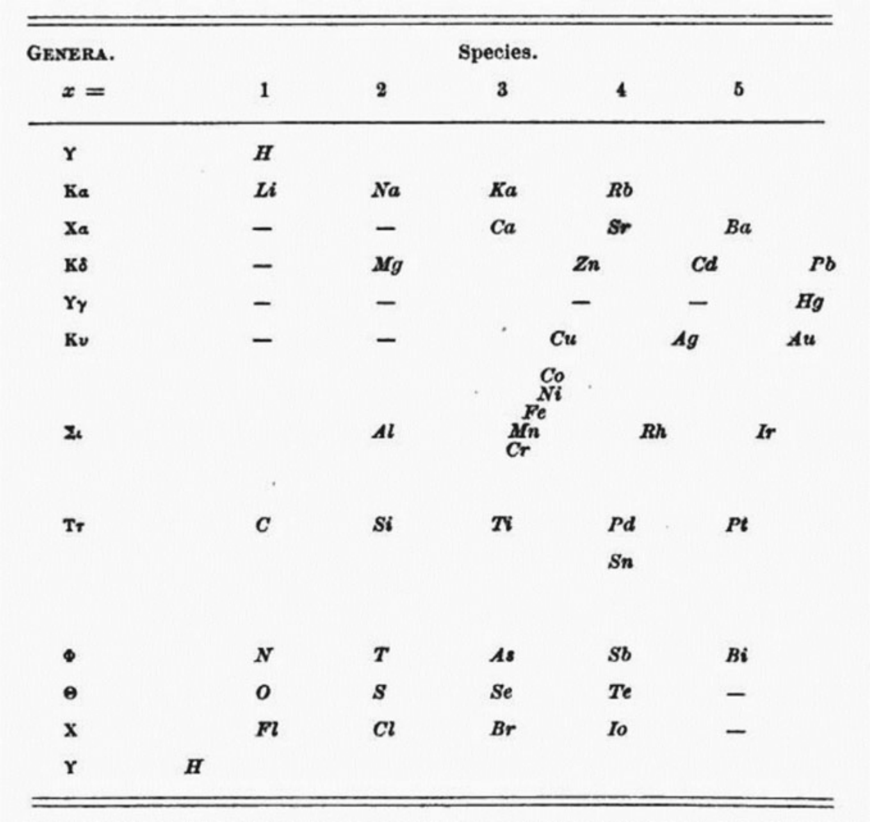
[19] In the English abstract of his *Programme* [2], Hinrichs states in reference to his mechanical theory of the forms of crystals, "The investigations of Gaudin are simply geometrical." So Hinrichs was aware of Gaudin's work.



GENERA.		Species.							
x =		1	2	3		4		5	
Y		H							
Ka		Li	Na	Ka		Rb			
Xa		—	—	Ca		Sr		Ba	
Kδ		—	Mg		Zn		Cd		Pb
Yγ		—	—		—		—		Hg
Kυ		—	—		Cu		Ag		Au
Σι			Al	Co Ni Fe Mn Cr		Rh		Ir	
Tτ		C	Si	Ti		Pd Sn		Pt	
Φ		N	T	As		Sb		Bi	
Θ		O	S	Se		Te		—	
X		Fl	Cl	Br		Io		—	
Y	H								

Fig. 7.15 Hinrichs's 1869 chart from *Proceedings of the AAAS Meeting* (1869) [4]

7.5 Hinrichs's Charts of 1869

Two years later, in 1869, Hinrichs published modified versions of his periodic system; one of them (Fig. 7.14) appeared in the July 1869 issue of a rather obscure Chicago-based journal, *The Pharmacist* [3], whereas the other (Fig. 7.15) was presented at the August 1869 meeting of the American Association for the Advancement of Science and published in their proceedings [4]. Hinrichs also issued his AAAS paper separately as a privately printed offprint [5]. The two new versions are very similar, the one presented at the AAAS meeting including fewer of the transition elements.

The tables also resemble Mendeleev's first table of 1869, in that the elements within a group are arranged in rows rather than columns. Mendeleev's table had appeared in the *Zeitschrift für Chemie* and the *Journal für praktische Chemie* a few months before Hinrichs's tables appeared, but it is unclear whether Hinrichs had seen it.

Several features of Hinrichs's 1869 tables have been discussed in some detail [6–9] and here I will just summarize some of the main conclusions.

(1) Hinrichs chose fusibility and volatility, i.e., "the deportment of the elements in increasing temperature, as the basis of classification. For heat is merely motion of the particles, in fact this classification is a mechanical one, expressing the relative mobility of the atoms of the elements …" [3] In a textbook Hinrichs published in 1871 [60], he elaborates:

> The order of the genera … is determined [as follows]. The least fusible and volatile is placed in the middle. The most fusible and volatile are at the top and at the bottom; the metals standing above, the metalloids below. The upper elements in this table are decidedly electropositive; the lower equally electronegative.

(2) Unlike his 1867 system, in which combining ratios played a dominant role, Hinrichs now uses his new organizational principles, fusibility, volatility, and electronegativity to reverse the relative ordering of the nitrogen and oxygen groups, so that in his 1869 system these groups are in the modern order, C–N–O–F. Although Hinrichs does not emphasize the point, this rearrangement also gives an order in which the atomic weights increase monotonically.

(3) Hinrichs points out [4] that

> in this table the elements of like properties, or their compounds of like properties, form groups bounded by simple lines. Thus a line drawn through C, As, Te, separates the elements having metallic lustre from those not having such lustre.

With regard to the last feature, it is relevant to point out that, in terms of overall structure, Hinrichs's 1869 system can be regarded as a long-form periodic table. Two aspects of the table support this conclusion. First, except for Pd and Pt, the transition elements are not co-mingled with pnictogen, chalcogen, or halogen groups: for example, V is not grouped with the pnictogens, Cr is not grouped with the chalcogens, and Mn is not grouped with the halogens, as they are in short-form tables. Second, the first-, second-, and third-row transition elements (except for Pd, Pt, and the elements in the Zn and Cu groups) collectively occupy the three places corresponding to the next three heavier congeners of aluminum. Hinrichs thus treats the transition elements the same way as the lanthanide and actinide elements are handled in many forms of today's periodic tables (i.e., as collectively occupying the two places after yttrium in group 3). This way of handling the transition elements is not like that in the short form of the periodic table; instead, Hinrichs's 1869 system is best regarded as a compacted version of a long-form periodic table.

Hinrichs points out that, in his 1869 table, a line can be drawn that separates the metals from the non-metals. This is the first recognition by anyone of this advantage of the long-form periodic table (although Gmelin had come close in 1843 [61]). Interestingly, Mendeleev emphasized that his system placed similar elements in adjacent locations, and he occasionally published long-form periodic tables (most notably in 1872 [62]), but as far as I know he never explicitly pointed out that the long form makes it possible to divide the metals and the non-metals with a single line. Hinrichs's idea was not resurrected until the Scottish chemist James Walker (1863–1935) independently recognized this advantage of the long-form table in 1891 [63].

In the longer of his two 1869 articles [4], Hinrichs proposes new formulas for the atomic weights of elements within a group. Instead of polynomials based on integers, Hinrichs now proposes formulas that include exponential quantities, but of course even these formulas do not match the experimental values exactly. He comments

> We do not mean to have the observed values corrected, for what here appears us "corrections" may in fact represent the links which hold together the various portions of the resulting atom. A negative correction would thus indicate that some projecting point had been removed before combination was effected.…

So here Hinrichs is proposing that his formulas give a sort of idealized atomic weight, which is modified when the atom engages in chemical combinations. He further says:

> Most chemists seem to think that the chief importance of the painstaking work of Stas is to disprove and forever reject the so-called hypothesis of Prout; and with the destruction of this hypothesis they seem to think all the palpable harmonies of the atomic weights, and particularly all relating to "pantogen" is annihilated. We are inclined to think that just such careful determinations will demonstrate the correctness of the law of a common divisor (equal one-half the atomic weight of hydrogen?) for all elements, and prove some essential features of the structure of the element atoms.

Hinrichs was nothing if not steadfast in his views.

Several additional aspects of the 1869 charts are worthy of comment. One is why the transition metals in Hinrichs's 1869 tables are listed in reverse order and in slanted columns. Van Spronsen has speculated [7, 8], I think correctly, that the reverse order "might also be explained by the fact that Hinrichs wanted in any case to see the elements Zn, Cd, and Pb classified as a group next to Mg." My sense is that the reverse order can also be viewed a holdover from his 1867 system, in which he proposed a reversal in the direction of the spiral beginning with titanium.

In reference to the arrangement in slanted columns, Hinrichs says in his 1869 AAAS article: "By printing their symbols at distances from that of the genus, nearly proportional to the atomic weight, we obtain the following chart …."[20] This sentence explains the slanting of the block of elements formed by the transition metals: the atomic weights of Zn, Cd, and Hg/Pb are the largest in their respective d-block rows, and thus they are placed farthest to the right.

But this explanation raises the question why the main group elements are not arranged with distances from the leftmost column "nearly proportional to the atomic weight". I found a possible answer in a copy of the handwritten original of his 1869 AAAS paper, which is present among the Hinrichs papers at the University of Illinois (Fig. 7.16).

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[20] By the word "genus," Hinrichs is referring to the leftmost column in the table, which lists what we would call groups.

Hinrichs' Classification of the Elements.

Genera

Species

Fig. 7.16 Handwritten original of Hinrichs's 1869 paper given to the American Association for the Advancement of Science. Courtesy of the University of Illinois at Urbana-Champaign

The dotted lines that precede each column of elements are slightly slanted with respect to the double line in the "genera" column, as they should, because the atomic weights increase in a period. I think it is possible that Hinrichs meant to have all the columns slanted in the printed table (i.e., with the bottoms of the columns set further right than the tops), but the typesetters didn't notice this subtlety and Hinrichs didn't insist on correcting it.

Another aspect of Hinrichs's 1869 tables is that they contain numerous gaps, but in neither of his 1869 publications does Hinrichs comment on the gaps in any way. Even if he had proposed that these gaps represented elements still to be discovered, however, his predictions would not have been borne out. For example, his placement of Ti, Pd, and Pt in the same group with C and Si made it impossible for him to predict the existence of germanium, and his grouping of aluminum with a number of transition metals (but not with boron) made it impossible for him to predict the existence of either scandium or gallium.

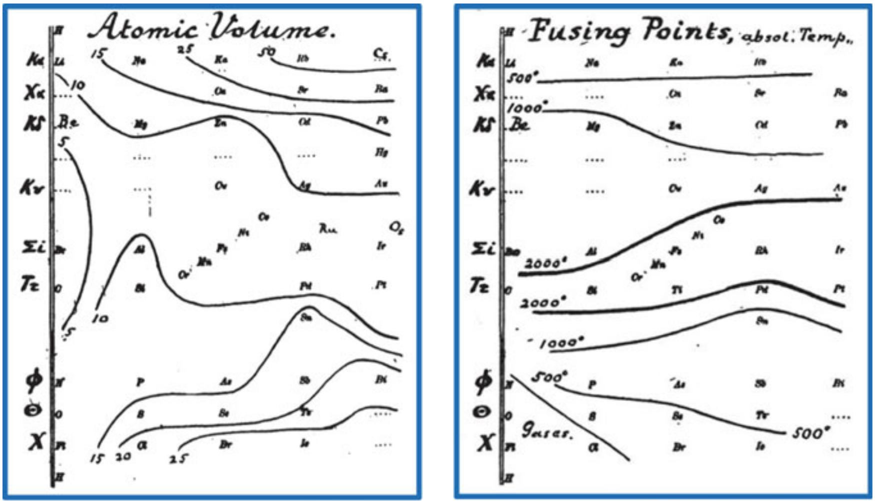

Fig. 7.17 Diagrams showing atomic volumes and melting points, mapped onto Hinrichs's 1869 table of the elements. From G. D. Hinrichs, *The Elements of Atom-Mechanics*, St. Louis, 1894

I will end with one aspect of Hinrichs's work that has largely been overlooked, which is his use of his system to illustrate periodic trends (Fig. 7.17). In a book he wrote in 1894 [56, pp. 231–239], Hinrichs gives examples of "some of the charts which were exhibited before the Salem Meeting of the American Association in August, 1869." In these charts, Hinrichs maps various chemical properties onto his 1869 table: among the properties he plots are atomic volume, fusing (i.e., melting) points, and specific gravity (i.e., density), but also the method and date of discovery of the elements, and reactions in the wet and dry way.

Hinrichs's atomic volume plot is especially notable for its anticipation of the important role that atomic volumes played in the formulation of the periodic systems of Lothar Meyer and Dmitri Mendeleev [64]. Of course, Hinrichs's plot was not published in 1869 and became available to the scientific public only after a lapse of 25 years.

7.6 Conclusions

Hinrichs used a number of chemical properties to construct his 1867 and 1869 periodic systems, including atomic weights, electronegativities, volatilities, valence, and specific gravities. In his 1869 article in *The Pharmacist*, Hinrichs states his approach as follows: "all the previous attempts [to classify the chemical elements] were founded upon only some one property of the elements, and hence necessarily led to an *artificial* classification." He was thus led "to propose a classification which we believe to be *natural*, because it does rest upon fundamental and essential properties, and because all other properties of the elements not directly involved in this classification nevertheless harmonize therewith" [3]. In a real way, he anticipated the holistic approach Mendeleev took when constructing his periodic system.

Both Hinrichs and Mendeleev used atomic weights as well as combining ratios to create their periodic systems, but Mendeleev placed greater importance on atomic weights as an organizing principle. As a result, Mendeleev's system not only more closely resembled today's periodic table, it facilitated his ability to make predictions about undiscovered elements, to correct incorrect atomic weights, and more generally to convince others that the system was useful.[21] Hinrichs's placing of greater importance on combining ratios led him initially to invert the relative locations of the nitrogen and oxygen groups, and his system was sufficiently flawed that it made it difficult for him to duplicate Mendeleev's achievements.

Hinrichs had a very ingenious theory for isomorphism, in which he proposed that chemical units such as ammonium and potassium, or cyanide and chloride, had similar shapes and sizes and thus formed crystals with similar shapes. He was entirely correct in general, but entirely wrong in his particular explanation.

The finding that Hinrichs's chart of 1867 is actually a double spiral—which begins in a clockwise fashion but then reverses direction and continues in a counterclockwise direction—stems simply from reading what Hinrichs wrote. The additional proposal that the transition elements in his 1869 system are arranged in a slanted fashion to reflect their relative atomic weights—whereas other elements are not arranged in this way owing to a printer's oversight—comes from a consultation of his original manuscripts.

Hinrichs was not well connected to other chemists, and was evidently unaware of (or uninterested in) many of the considerable developments that had taken place in chemistry in the decade or so leading up to 1867. There is, for example, no hint of the "new" structural organic chemistry in any of his publications before 1870. It seems that, at the time he constructed his *Atomechanics*, Hinrichs's knowledge of chemistry was based almost entirely on what he learned as a student in the early 1850s, augmented by some selected reading of more recent chemical papers (Dumas's 1858 paper for example).

Hinrichs never carried out chemical research of his own and, after he moved to the United States, he was scientifically isolated and kept busy with his instructional and organizational duties. Very likely, he had little time or opportunity to keep up with the newest ideas. Thus, in the field of chemistry Hinrichs was, to a great degree, intellectually frozen in the 1850s. From this perspective, it is even more remarkable that he was able to devise a periodic system at all.

To call Hinrichs a crank, as some have, is in my opinion an oversimplification. To be sure, he invented novel comprehensive systems in vastly divergent areas of science, often proposing new vocabulary that proved more of a barrier than an aid to understanding. He was often guilty of forcing data to fit a preconceived idea, and finding more meaning in correlations and trends than actually exist. He resorted to

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[21] For a detailed discussion of this topic, see Ann Robinson's Chap. 1 in this volume.

private publication when he could not get his ideas into the mainstream scientific press; furthermore, he distributed his *Atomechanics*, his magnum opus, as a lithographed handwritten manuscript rather than a printed monograph. He sent his work to influential people, such as Darwin and Humboldt, even when it was far outside their area of expertise. He accused established scientists of either ignoring his ideas or trying to steal them.

Such behavior is certainly displayed by true cranks, but many of these tendencies are also displayed by those who, like Hinrichs, are outside the scientific mainstream. For example, not long before, in the 1840s, both Julius Robert Mayer (1814–1878) and Hermann Helmholtz (1821–1894) resorted to private distribution of their philosophical (and rather hand-wavy) ideas on the conservation of energy when they could not get them published; also like Hinrichs, their ideas were largely ignored at the time, and both later became involved in priority disputes [65].

In my view, Hinrichs was a polymath with an encyclopedic (if not completely up-to-date) knowledge of the natural world. His unpublished work, as it survives in the University of Illinois archives, is massive in quantity (multiple large handwritten volumes) and impressive both in scope and content. Although ultimately his penchant for uncritical systematizing prevented him from devising a more compelling periodic system, Hinrichs deserves credit for being one of the first to organize the chemical elements into a useful two-dimensional arrangement having both groups and periods based on increasing atomic weights, and to point out that many properties of the elements change in systematic ways not only within a group but also between them.

Acknowledgements I thank the William and Janet Lycan Fund of the University of Illinois for support, and Alan Rocke, Carmen Giunta, and Vera Mainz for numerous helpful suggestions.

Appendix: Transcription and Translation of Hinrichs's 1867 Monograph

Note: Underlining (which Hinrichs uses liberally) and figures are generally omitted from this transcript.

Atomechanik oder die Chemie eine Mechanik der Panatome	**Atomechanics or Chemistry a Mechanics of Panatoms**
(French title)	**(French title)**
Von Gustav Hinrichs	**By Gustav Hinrichs**
Professor der Physik, Chemie & Mineralogie an der Staats-Universitat, Chemiker der geologischen Survey des Staates Iowa, etc.	**Professor of Physics, Chemistry & Mineralogy at the State University, Chemist of the Geological Survey of the State of Iowa, etc.**
Iowa City, Vereinigte Staaten, N[ord] A[merika] 1867	**Iowa City, United State, North America 1867**
Geschichtliche Vorbemerkung	**Historical Foreword**
1855. Durch Untersuchungen über das Verhältniss der Wärme zum Licht und namentlich über die Erzeugung beider, wurde ich Anfang Februar 1855 auf das Princip geführt, worauf gegenwärtige Atomechanik fusst, nämlich das von der Existenz eines einzigen Elementes.	1855. By investigations of the relation of heat to light, and especially of the production of both, I was led to the principle at the beginning of February, 1855, on which the present atomechanics is based, namely, that of the existence of a single element.
Ich begann sogleich dieses Princip zu beweisen durch Ableitung von Folgerungen und Vergleich derselben mit den Resultaten der Erfahrung. Mehrere Personen in Kopenhagen, wo ich der Zeit studirte, machte ich mehr oder weniger ausführliche Mitteilungen darüber. So auch meinem betrauerten Lehrer, Professor G. Forchhammer.	I immediately began to test this principle by deriving conclusions and comparing them with the empirical results. Several persons in Copenhagen, where I studied at the time, made more or less detailed communications about it. So did my lamented teacher, Professor G. Forchhammer.
Eine Zeichenschrift des Titels „Hinrichssche Naturphilosophi[e]" enthaltend die Principien und einige bereits erlangter Hauptfolgerungen liess ich unteren 7te August obrigkeitlich beglaubigen. Dieses Schriftstück ist auch in meinem Besitz.	I officially certified on the 7th of August a document in characters entitled "Hinrichs's Naturphilosophie" containing the principles and some of the main conclusions already obtained. This document is also in my possession.
1856. Im October dieses Jahres glaubte ich hinreichend weit fortgeschritten in meiner Arbeit um an die Veröffentlichung zu schreiben. Ich sandte zu dem Ende kürzerer Anzeigen an viele der bestanden Männer der Wissenschaft und auch an einige Akademien, erwartend dass mir dadurch die wissenschaftlichen Zuschriften für das Nähere eröffnet werden wurden. Darin hatte ich mich aber sehr verrechnet. Ich sollte durch passiven Widerstand und den Mangel an Hielfe [sic] dazu gebracht werden, die Atomechanik noch merher [sic for mehrer] auszubilden.	1856. In October of this year, I thought I was sufficiently advanced in my work to rewrite the publication. I ended up sending shorter reports to many of the existing men of science and also to some academies, expecting this to open up closer scientific communication. I had miscalculated in that. Passive resistance and the lack of help were to persuade me to further develop atomechanics.

1856/7. Folgend Herren und Institute erhielten kürzere oder längerer Mittheilungen von mir: G. Forchhammer, Kopenhagen; John Tyndall und ausserdem die Editors of the Philosph[ical] Magazine, London; l'académie des sciences, sowie M. E. Arnoult, Redakteur des „Institut" u[nd] a[ndere] in Paris; Poggendorff, Krönig, A. Dubois Reymond, die physikalische Gesellschaft, in Berlin; W. Haidinger, A. Schrötter, K[önigliche] Akad[emie] der Wissenschaften, in Wien; Hansen in Gotha, v[on] Humboldt, Berlin, etc. etc. Alle diese Mitteilungen wurden Anfang 1857 oder in den letzten quartal 1856 abgegeben.

Wenn vielleicht Keine dieser Schriften gedruckt wurde, so darf ich dieselben doch als Veröffentlichung meiner Idee und der Auffassung sowie der Theilweisen Hörung des Problems anzusehen berechtigt sein. Denn obige Namen zeigen dass die ihnen gewordene Mitteilung dem durch Druck fast gleiche kommt; jedenfalls aber hatte ich zur Veröffentlichung alles mir mögliche gethan.

Trotzdem dass meine damaligen Mitteilungen sehr schwach waren, so war doch das ganze Problem der Atomechanik deutlich und klar aufgefasst, und deren Lösung bereits vielfach hervor geführt.

Die ausführlichsten Mitteilungen gingen an Forchhammer in Kopenhagen, an A. Krönig in Berlin für die physikalischen Gesellschaft, deren Schriftführer er damals war, und an Dr. W. Haidinger in Wien für die wesentlich von ihm ins Leben gerufener K[onigliche] Akademie der Wissenschaften.

Der jetzt schon entschlafene Forchhammer hat sich mehrfach für meine ferneren Arbeiten verwendet durch seinen grossen Einfluss in der dänischen Residenz. Seinem Andenken alle Ehre! Er führte mich sowohl in die Chemie als in der Krystallographie ein.

Der humane W. Haidinger schrieb mir unverzüglich in einer Weise, die dem Manne eben so sehr zum Ehre geneigt, wie die grossen wissenschaftlichen Arbeiten in ihm den ausgezeichneten Gelehrten zur Geltung gebracht haben. Dass er dem jugendlichen Ungestüm Rechnung trug und Nachsicht übte danke ich dem hochwürdigen Greise nochmals.

1856/7. The following gentlemen and institutes received shorter or longer reports from me: G. Forchhammer, Copenhagen; John Tyndall and also the Editors of the Philosphical Magazine, London; l'académie des sciences, as well as Mr. E. Arnoult, editor of "L'Institut" and others in Paris; Poggendorff, Krönig, A. Dubois Reymond, the Physical Society, in Berlin; W. Haidinger, A. Schröther, Royal Academy of Sciences, in Vienna; Hansen in Gotha, von Humboldt, Berlin, etc. etc. All of these communications were made in early 1857 or in the last quarter of 1856.

Even if none of these documents was printed, I may be entitled to regard them as a publication of my idea and of my opinion as well as the partial hearing of the problem. Because the above names show that the communication they received is almost the same as the printed one; at least I had done everything I could to publish it.

In spite of the fact that my communications at the time were very weak, the whole problem of atomechanics was distinctly and clearly understood, and whose solution had already been given multiple times.

The most detailed communications went to Forchhammer in Copenhagen, to A. Krönig in Berlin for the physical society of which he was the secretary at the time, and to Dr. W. Haidinger in Vienna for the Royal Academy of Sciences, which he essentially founded.

The now departed Forchhammer has several times applied for my further work due to his great influence in the Danish royal capital. All honor to his memory! He introduced me to both chemistry and crystallography.

The humane W. Haidinger immediately wrote to me in a way just as much to the man's honor as the great scientific work brought out the excellent scholar in him. I thank the venerable old man once again that he took account of youthful impetuosity and practiced forbearance.

Herr Dr. A. Krönig antwortet mir auf meine Zuschrift vom 26 Januar 1857 erst unteren 15 April 1857, und zwar nachdem ich mich bei dem Secretär der Gesellschaft geschickter Arbeit erkundigt hatte. Er sagt: „Ich habe Ihre Abhandlung mit Aufmerksamkeit durchgelesen …“ sie aber nicht imstande dieselbe der Gesellschaft vorzutragen, da er als dann dieselbe zu vertreten haben würde; u[nd] fährt fort: Um übrigens, so viel in meinen Kräften steht dafür zu thun, dass Ihre Atomechanik den Mitgliedern der physikalischen Gesellschaft bekannt wird, will ich dieselbe morgen unseren Lesezirkel übergehen, wo sie in die Hände jeden einzelner Mitglieder gelangt: Hatte Krönig die Abhandlung in dem Vierteljahr seit dem Empfang dieselbe der Gesellschaft noch gar nicht angezeigt.	Dr. A. Krönig replied to my letter of January 26, 1857 only at the end of April 15, 1857, after I had inquired about the work sent to the secretary of the Society. He said: “I read your paper carefully…” but was not in a position to present it to the Society, because then he would be responsible for it; and he continued: In order to ensure to the best of my power that your atomechanics becomes known to the members of the Physical Society, I want to pass it on to our reading circle tomorrow, where it will get into the hands of each individual member: Krönig had not reported the paper to the Society even in the quarter since it was received.
Kürzlich habe ich die mit so vielen und so humanem (!) Eifer von Herrn Krönig an Liebig gerichtete „Werthlosigkeit etc.“ sowie das „Neues Verfahren etc.“ Berlin, 1866 gelegen. Mit mir wird jeder Wissenschaftsmann die ernste und würdige Vertretung der freien Forschung und des ungehinderten Fortschritte darin gebührend würdigen. Am Schlusse des „Neuen Verfahrens“ dem die „Werthlosigkeit“ vorangestellt ist, scheint in der That ein wirklich neues Verfahren offenbar, zu sein!	Recently I have received the [monographs] "Worthlessness etc." as well as "New Procedure etc." Berlin, 1866, which Mr. Krönig addressed to Liebig with so much and so humane (!) zeal. Every scientist will duly honor with me the serious and worthy representation of free research and the unhindered progress in it. At the end of the "New Procedure", which is preceded by "Worthlessness", a really new process seems indeed to be evident.

[Translator’s note: Krönig’s monograph *Neues Verfahren zur Ableitung der Formel einer Verbindung aus den Gewichtmengen der Bestandtheile* (*New Procedure for Deriving the Formula of a Compound from the Weights of the Constituent Parts*), was issued with another by Krönig, entitled *Die werthlosigkeit einer grossen Anzahl von chemischen Formeln* (*The Worthlessness of a Large Number of Chemical Formulas*). In this latter monograph, Krönig argued that assigning a definite formula to many chemical substances was often unjustified. For example, he showed that the then-current analytical data for linoleic acid (Leinölsäure) were consistent with formulas having between 16 and 18 carbon atoms – and between 29 and 31 hydrogen atoms – for every 2 oxygen atoms (in terms of modern atomic weights; Krönig used H = 1, C = 6, O = 8). The modern formula for linolenic acid is $C_{18}H_{32}O_2$.]

Er heisst nämlich s[iehe] ob[en] im „Neuen Verfahren“ dass der Herr Krönig sich zu den Verehrern der in neuester Zeit auch von Graham befürworteten Hypothese von der Einheit der Materie zähle! Meine ihm geschickte Abhandlung gehört ja schon nicht mehr der neuesten Zeit an, sondern 1856 und 1857. Seite 53, immer in „Neuen Verfahren“: „Ich habe … Ende 1863 … ein eigenes (!) System von Atomgewichten aufgestellt. Dieselben unterscheiden sich von den Berzelius’schen fast nur hinsichtlich der Einheit auf welche sie be-	Namely, see above in the “New Procedure” that Mr. Krönig is one of the admirers of the hypothesis of the unity of matter, which Graham has recently also advocated! My treatise sent to him is no longer up to date, but [is from] 1856 and 1857. Page 53, again in "New Procedure" [Here Hinrichs quotes from Krönig’s monograph, adding an exclamation point]: "At the end of 1863 ... I set up my own (!) system of atomic weights. They differ from Berzelius’s almost exclusively in terms of the unit to which they

zogen sind.“ Aber Herr Krönig, in unterscheiden sich in nichts von denen ihnen in meiner Abhandlung vom Januar 1857 als dem Sekretär der physikalischen Gesellschaft anvertrauten Atomzahlen (für welcher Vertrauen Sie beruflich in 1857 dankten; doch das war vor dem Neuen Verfahren!) Ferner (S[eite] 56) Ich setze also H = 2, O = 32, Cl = 71, Ca = 80, etc u[nd] sagt auch noch: chlor betrachte Er als aus 71 Molekülen bestehend u[nd] s[o] w[eiter].

Es wird nicht nöthig sein, diesem ein Mehreres hinzuzufügen. Ich gehe es den Vertretern der Wissenschaft anheim, und namentlich meinen Landsleuten unter diesen, u[nd] als solche betrachte ich selbstverständlich alle Deutsche. Ich beklage mich nicht darüber dass ich damals kein grösserer Entgegenkommen fand; denn ich blicke jetzt als mehrfahrener u[nd] durch Schicksalsschlage gereifter kann auf den jugendlichen vertrauensvollen und selbst überschätzenden Enthusiasmus zurück. Ich danke es Männern wie Haidinger, du Bois Raymond [sic], Forchhammer u[nd] a[ndere] wenn dieselben in dem jugendlichen Enthusiasmus einen zu achtenden Kern entdecken; aber wer im Stande ist, erst eine anvertraute Entdeckung zurückzuhalten dann zu verwerfen – u[nd] nachdem der Kämpfend, sein Leben für die Idee, all seine Thatkraft der Entwickelung derselben widmend Jüngling der Ungunst politischer Umstande weichend (ich bin Schleswig-Holsteiner u[nd] Deutscher ! war aber in Kopenhagen) den fernsten Westen aufsuchen muss dort trotz aller Schwierigkeiten fortfährt an der Lebensaufgabe zu arbeiten – je nachdem 6 Jahren des Kampfes und Schweigens vielleicht ein „Verschollen“ wahrscheinlich machen – wir dann nach einem Gott sei Dank neuen oder doch seltenen Verfahren dieselben Ideen, die ihm als Officier einer gelehrten Gesellschaft anvertraut wurden in kaum verändertet Gestalt – u[nd] mir es scheint Kaum weiter entwickelt! – als Eigene Arbeit veröffentlicht – ein[?]bringt man einfach vor das Forum der strebenden Fachmänner. Damit übergebe ich diese Sache der Männern der Wissenschaft, besonders in Deutschland.

Ferner habe ich dieses Fundamental-Princip (Pantogen oder Urstoff) ausgesprochen bei folgenden Gelegenheiten:

relate.” But Mr. Krönig, there are no differences between yours and the atomic numbers in my treatise from January 1857 that I entrusted to the secretary of the Physical Society (for which trust you thanked [me] professionally in 1857; but that was before the New Procedure!) Furthermore (page 56) [Krönig says] I put H = 2, O = 32, Cl = 71, Ca = 80, etc., and also [he] says: He regards chlorine as consisting of 71 molecules etc.

It will not be necessary to add more to it. I leave that to the representatives of science, and especially my compatriots among them, and as such I naturally consider all Germans. I do not complain about the fact that I did not find a greater accommodation at the time; because I can now look back as a more experienced and more mature man on the youthful, trusting and overestimating enthusiasm. I thank men like Haidinger, du Bois Reymond, Forchhammer and others when they discover a kernel to be respected in youthful enthusiasm. But who is able first to quash a confided discovery and then to reject it – after struggling, devoting his life to the idea [and] all his energy to developing it, giving way to the unfavorability of political circumstances (I'm from Schleswig-Holstein and German! but was in Copenhagen) and having to go to the distant west despite difficulties to continue working there on the life's work. Depending on 6 years of struggle and silence, perhaps making “lost without a trace” probable – we then have, according to (praise God!) [Here Hinrichs is being sarcastic, and in the next sentence alludes to Krönig’s “New Procedure”] a new or at least unusual procedure, the same ideas that were entrusted to him as an officer of a learned society, in hardly changed form – and as it seems to me hardly developed further! – published as his own work – [and] simply put in front of the forum of aspiring experts. Thereby I hand this matter over to men of science, especially in Germany.

I have also expressed this fundamental principle (pantogen or primordial substance) on the following occasions:

1860 – Versammlung die skandinavischer Naturforscher, Juli 1860, Kopenhagen. Auch meine Schrift „Die Erdmagnetismus als Folge der Bewegung der Erde in Aether." Kopenhagen 1860, S. 8, §15.	1860 – Meeting of the Scandinavian Naturalists, July 1860, Copenhagen. Also my paper "The Earth's Magnetism as a Result of the Movement of the Earth in Aether." Copenhagen 1860, p. 8, §15.
1865 – Introduction to the mathematical principles of the nebular theory or Planetology, Silliman's Journal, 1865, Bd. 39 p. 65 im §6. Hier ist wiederum dasselbe Princip ausgesprochen. In dieser Schrift ist unter anderer beweisen, dass die Planeten nach gleichen Zeitintervallen euch vom Centralkörper ablösten, so dass die Bewegung eine Pulsation, Schwingung war.	1865 – Introduction to the mathematical principles of the nebular theory or Planetology, Silliman's Journal, 1865, vol. 39 p. 65 in §6. Here again the same principle is expressed. This document proves, among other things, that the planets detached themselves at equal time intervals from the central body, so that the movement was a pulsation, vibration.
Im Sommer und Herbst desselben Jahres war ich schon nicht weit mit meine Krystallographischen Arbeit, basirt auf die Constitution der Salze wie gegenwärtig angenommen in dieser Schrift. Der Tod meines Lebensgefährten setzte aber meinem Wissenschaftlichen Werke einstweilen ein Ziel. 12 October 1865.	In summer and autumn of the same year I was not far with my crystallographic work, based on the constitution of the salts as currently assumed in this document. The death of my life's companion [wife], however, set a goal for my scientific work for the time being. 12 October 1865.
1866 Im Novemberhefte von Silliman's Journal ist meine Abhandlung „On the Spectra and Composition of the Elements" vol 42, p. 364 unter §30 gebe ich einige Formeln für Genera, dort aber alle auf den rectangulären Base bezeigen. Hier mag es gesagt sein, dass ich viele hundert Gesetze versucht habe, ehe ich mit dem jetzigen Zufrieden war (siehe 21 etc. dieses Schrift).	1866 In the November issue of Silliman's Journal is my treatise "On the Spectra and Composition of the Elements" vol. 42, p. 364 under §30 I give some formulas for genera, but all point to the rectangular base there. It may be said here that I tried many hundreds of laws before I was satisfied with the present one (see 21 etc. of this paper).
Schon letzten Herbst kam ich mit Dana, einern der Herausgeber des American Journal, zu einen Verständnis über die Veröffentlichung meine Arbeit in diesem Journal; 15 Seiten in jeder Nummer. Einen frühern Verständnisse gemäss wollte ich mit dem Krystallographischen Theile anfangen, inductiv bis zum Pantogen hinarbeiten. Es meiner mehr als ein Jahr darüber vergangen sein, ehe ich auch nur die Hauptsachen würd angeregt haben. Umstände haben die gegenwärtige Veröffentlichung hervorgerufen.	Last fall I came to an understanding with Dana, one of the editors of the American Journal, about the publication of my work in this journal; 15 pages in each number. According to an earlier understanding, I wanted to start with the crystallographic part, [and] work inductively to the pantogen. It must have been more than a year since I even suggested the main points. Circumstances have caused the current publication.
Hiermit übergebe ich diese Arbeit dem wissenschaftlichen Publikum. Es ist die Frucht ernsten Strebens, und unverdrossener Ausdauer. Sie ist unvollkommen – unendlich unvollkommen vergleichen mit dem Ideale das mir vorschwebte, und dem ich mich stets zu nahern suchte. Aber ich glaube dass man doch darin einen Fortschritt der Wissenschaft finden wird.	I hereby hand over this work to the scientific audience. It is the fruit of serious striving and undaunted perseverance. It is imperfect - infinitely imperfect compared to the ideal that I had in mind and to which I always tried to approach. But I think you will find progress in science in it.

So mögen denn andre Kräfte, unter günstigern Verhältnissen mit grösseren Fähigkeiten und bedeutenderen Mitteln diesen Weg fruchtbringend finden.	So other forces may find this path fruitful under more favorable conditions with greater abilities and more important means.
Möge dieses Arbeit der Wissenschaft als ein Beitrag zum wahren Fortschritt erscheinen! Das war mein Wunsch und mein ernstes Streben während der langen, frühen Jahre die seit der jugendlichen Sturm und Drang periode in 1856 u[nd] 1857 verflossen!	May this work of science appear as a contribution to true progress! That was my wish and my serious pursuit during the long, early years that had passed since the juvenile Sturm und Drang period in 1856 and 1857!
Gustavus Hinrichs, Iowa City, im Staat Iowa; Redaktion von Novbr 1866 – Juni 1867	Gustavus Hinrichs, Iowa City, in the state of Iowa; Edition of November 1866 – June 1867
Bei der wissenschaftlich fast isolirten Stellung werden Briefe von Fachmännern wir sehr wollkommen sein; jede Meinung ab für oder wider, ist mir gleich werth. Man addressiere:	In the scientifically almost isolated location, letters from experts will be very welcome; any opinion for or against is of equal value to me. One addresses:
Prof. Gustavus Hinrichs Iowa City Im Staat Iowa U. St. Nord Amerika	Prof. Gustavus Hinrichs Iowa City Iowa U. S., North America
Nur unter diese Addresse sind Briefs der Bestellung sicher. Wenn Briefe, wie neulich, bloss – Iowa US – als Localbezeichnung habend, sich ankommen, ist es ein reiner Zufall.	Only at this address are letters of order certain [to arrive]. If letters, like the other day, only have – Iowa US – as the local name, their arrival is a pure coincidence.
Vocabulaire	**Vocabulary**
Atomechanik – für Mechanik der Atome	Atomechanik – for mechanics of atoms
Ato – für Atom in Zusammensetzungen, wie	Ato – for atom in combinations, like
Atometer (*m*) Maass, Hohe der Atom, §.14. Atobar, der schwere Theil des Atoms, §.123 Atostere, der Gesammtraum des Atoms, §.20 Atogramme, das Gewicht des Atoms, §.14 Atomare, *a*, das Areal oder der Durchschnitt des At[oms], §.14	Atometer (*m*) measure, height of the atom, §.14. Atobar, the heavy part of the atom, §.123 Atostere, the total space of the atom, §.20 Atogramme, the weight of the atom, §.14 Atomare, *a*, the area or the base of the atom, §.14
Pantogen oder Panogen, §.3 Panatom oder Pantatom, §.7 Trigonoid, etc. §.10 u[nd] s[o] w[eiter].	Pantogen or Panogen, §.3 Panatom or Pantatom, §.7 Trigonoid, etc. §.10 and so on.
Einleitung	**Introduction**
1. Es giebt überhaupt keinen absoluten Unterschied zwischen den chemischen Elementen. Dieselben physikalischen und chemischen Eigenschaften finden sich bei allen	1. There is no absolute difference between the chemical elements. The same physical and chemical properties are found in all elements, only in different magnitude. Therefore,

Elementen wieder, nur in verschiedener Grösse. Daher dürften dieselben füglich als quantitative Modificationen eines Stoffes zur betrachten sein. Diese Annahme wäre auch an sich philosophischer, als die der Ursprünglichkeit der vielen chemischen Elemente.	they may be considered as quantitative modifications of a [common] substance. This assumption would also be more than [the assumption] of the originality [unrelatedness?] of the many chemical elements.
2. Es ist daher eine wichtige und legitime Aufgabe der Wissenschaft zu erforschen ob diese Annahme in ihren mathematischen Folgerungen nicht nur genügt, die chemischen Elemente in ihren Eigenschaften darzustellen, wie die Gravitation die Bewegungen der Planeten ausdrückt; sondern auch die bekannten Gesetze der chemischen Verbindungen erklärt als rein mechanische Folgen neue Gesetze entdeckt und vor Allem auch den lange gesuchten Schlüssel zu den Krystallformen und den mit derselben so wesentlich modificirten physikalischen Eigenschaften an die Hand giebt – etwa wie die Gravitation auch die kleinern Abweichungen als Perturbationen nachwies, selbst Form und Dichte bestimmte und gar Planeten (Neptun) und Sonnen (Companion des Sirius) errechnete. Wir werden manche bis jetzt unbekannte Elemente andeuten.	2. It is therefore an important and legitimate task of science to investigate whether this assumption in its mathematical conclusions is not only sufficient to show the properties of the chemical elements, [and] how gravity expresses the movements of the planets; but also the known laws of chemical compounds are explained as purely mechanical consequences of newly discovered laws and, above all, the long-sought-after key to crystal forms and the physical properties that have been so significantly modified with them - such as how gravitation also calculated the smaller deviations as perturbations, even determined shape and density and even calculated planets (Neptune) and suns (companion of Sirius). We will hint at some previously unknown elements.
3. Wir wollen daher annehmen, dass Alles der materiellen Natur aus einem einsigen [sic for einstigen] Stoffe hervorgegangen ist. Dieses ursprüngliche Element nennen wir füglich Pantogen.	3. We therefore want to assume that everything of a material nature has arisen from a former substance. We may call this original element pantogen.
4. In den vorliegenden Blättern gebe ich nur eine vorläufige Anzeige, einen Ueberblick meiner Arbeit, doch hinreichend dass der Fachmann ein bestimmtes Urtheil über dieselbe erlangen kann. In den der Physik und Chemie gewidmeten Zeitschriften hoffe ich zur vollständigern Darlegung der Beweise Gelegenheit zu bekommen. Wenn meine Theorie als auf gesunder Basis ruhend und den Weg zeigend zur Ergründung der Constitution der Materie, erkannt wird, so ist meine Aufgabe gelöst. Den vollständingen Aufbau muss grössern und mannigfältigern Kräften vorbehalten bleiben.	4. In the present pages I give only a preliminary announcement, an overview of my work, but sufficient that the expert can get a certain judgment about it. In the journals devoted to physics and chemistry, I hope to have the opportunity to fully present the evidence. If my theory is recognized as resting on a healthy base and pointing the way to the exploration of the constitution of matter, then my task is solved. The complete structure must be reserved for large and varied forces.
5. In dem felsenfesten Vertrauen auf die Universalität und Einheit der Gesetze der Mechanik und in dem durch ernstes und unbefangener Studium der exacten	5. This work is rooted in the rock-solid trust in the universality and unity of the laws of mechanics and in the fact that through serious and impartial study of the exact

Wissenschaften erlanget Bewusst sein, dass die chemischen Processe ebenso sehr wie die Planeten Bewegungen einfache mechanische Bewegungs-Erscheinungen sind, wurzelt diese Arbeit; die mich in beiden Hemisphären, unter drei verschiedenen Nationen und mannigfachen Wechselfällen schon reichlich zwölf Jahre beschäftigt hat. Als Knabe las ich dass die Physik in mechanische und chemische Physik eingetheilt werde; Wärme und Electricität gehörten zur chemischen (!) Physik. Als ich Student war zeigten die Lehrbücher die ganze Physik schon als mechanische Wissenschaft. Jetzt giebt es schon eine schöne physikalische Chemie – welch ein Fortschritt seit den Tagen der chemischen Physik. Ich versuche jetzt eine Chemie als Mechanik, die Mechanik der Atome, wie Astronomie die Mechanik der Himmelskörper – die auch nur kosmische Atome sind.

Erster Abschnitt. Das Pantogen und die Elemente.

6. Die Hypothese. Das Pantogen besteht aus gegenseitig gleichen Atomen, die sich gegenseitig anziehen und durch Wärme oder Bewegung von einander gehalten werden.

Diese Atome sind hier selbstverständlich als materielle Puncte der Mechanik zu betrachten; Keinerlei occulte Eigenschaften dürfen ihnen beigelegt.

7. Pantogen Atom kürzen wir ab als Pantatom; das Gewicht eines solchen setzen wir als Einheit. Das Gewicht irgend einer Anzahl *n* Pantatome ist also = *n*.

8. Freier Pantogen kommt wahrscheinlich vor in der äussersten Sonnenatmosphäre (wirkt lichterregend) und in den planetarischen Nebeln. Wasserstoff steht demselben am nächsten. Verhältniss zum Lichtäther bleibe dahingestellt.

9. Zur Darstellung erscheinen im Folgenden als am Geeignetsten: die schwereren Alkali-Metalle (Ka, Rb), ferner Cl, P, Sb, S; Ca, Sr, Ba, u[nd] a[ndere] Dissociations Versuche müssen mit Hülfe hoher Hitzegrade oder electrischer Spannung angestellt werden.

10. Verbindungsweisen in einer Ebene sind für gleiche materielle Punkte nur zwei mög-

sciences, that chemical processes are phenomena involving simple mechanical movement just like planetary movements; this has occupied me in both hemispheres, among three different nations and manifold vicissitudes for a good twelve years. As a boy I read that physics is divided into mechanical and chemical physics; Heat and electricity were part of chemical (!) Physics. When I was a student, textbooks showed all of physics as a mechanical science. Now there is beautiful physical chemistry – what progress since the days of chemical physics. I am now trying chemistry as mechanics, the mechanics of atoms, like astronomy is the mechanics of celestial bodies – which are also just cosmic atoms.

First section. Pantogen and the Elements.

6. The hypothesis. Pantogen consists of mutually identical atoms, which attract each other and are held to one another by heat or movement.

These atoms are here of course to be regarded as material points of mechanics; no occult features may be attached to them.

7. Pantogen atom we abbreviate as pantatom; the weight of such we set as unity. The weight in a number *n* of pantatoms is therefore = *n*.

8. Free pantogen probably occurs in the outermost solar atmosphere (appears light-producing) and in the planetary nebulae. Hydrogen is closest to it. The relationship to the luminiferous ether remains undecided.

9. For the purposes of illustration, the following are the most significant: the heavier alkali metals (Ka, Rb), furthermore Cl, P, Sb, S; Ca, Sr, Ba, among others. Dissociation experiments must be carried out with a high degree of heat or electrical tension.

10. There are only two possible compound arrangements in a plane for equal material

lich: als Ecken eines gleichseitigen Dreiecks oder quadrats. Demgemäss ergeben sich zweierlei Pantogen-Verbindungen oder Elemente; nämlich Trigonoide und Tetragonoide.	points: at the corners of an equilateral triangle or a square. Accordingly, there are two kinds of pantogen compounds or elements; namely trigonoids and tetragonoids.
11. Regelmässige Trigonoid-Formen sind die beistehenden. Jeder Punkt bezeichnet einem Pantatom. Als Kurze Bezeichnung dieser Formen gebrauchen wir im Folgenden eine der beiden nebenstehenden, je nachdem Seitenzahl oder Pantatomzahl der Figur erfordert wird.	11. Regular trigonoid forms are the [ones shown] adjacent. Each point denotes a pantatom. As a short description of these forms, we have described below one of the two ones [shown] adjacent, depending on the number of sides or the number of the number of atoms in the Figure.

[Translator's note: Calculations are given here, related to Figs. 11a-f, on the number of points in six- and four-sided rafts of having sides of equal length. For hexagons, the series is 1, 7, 19, … and for squares is 4, 9, 16, ….]

Uebergangsformen die sehr einfach sind und wirklich vorkommen sind.	Transitional forms that are very simple and that really occur.

[Translator's note: Calculations are given here, related to Figs 11g-i, on certain six-sided rafts having sides of unequal length; examples include those with 13, 23, and 23 [sic; should be 30] points.]

Figur [11]h′ ist 33 [sic for 34]. Kommt nicht vor.	Figure 11h′ [a hexagonal raft with unequal sides] is 34 [points]. Does not occur.
12. Tetragonoid-Formen [Figs 11k-m] sind, als Vorkommend quadrat $4^2 = 16$, Rechteck [4·3] =12, [4·5] = 20 und deren Multipla.	12. Tetragonoid forms [Figs 11k-m] are, as the previous square $4^2 = 16$, rectangle [4·3] = 12, [4·5] = 20 and their multiples.
13. Indem diese Pantatom-Platten sich vertikal übereinander lagern entstehen Prismen als die Atome der Elemente. Diese Lagerung ist durch die Mechanik absolute geboten.	13. By placing these pantatom plates vertically above one another, prisms emerge as the atoms of the elements. This arrangement is absolutely required by the mechanics.
14. Die Basis oder der Durschnitt [sic] dieser Prismen (obige Figuren) nennen wir Atomare (areal) und bezeichnen es durch a. Die Anzahl solcher Platten giebt die Höhe der Prismen; wir nennen es Atometer, da es das Maass [sic] der verschiedenen Glieder die zur gleichen Basis gehören ist. Wenn nur ein Prisma, so ist die Gesammtsumme der Pantatome im Element-Atom oder das Atomgewicht = Atogramme $g = m{\cdot}a$ (siehe §.7.)	14. We call the base or section of these prisms (above figures) atomare (areal) and designate it by a. The number of such plates gives the height of the prisms; we call it the atometer, because it is the measure of the various members that belong to the same base. If there is only one prism, then the sum total of the pantatoms in the element atom or the atomic weight = atogram $g = m{\cdot}a$ (see §.7.)
15. Es ergiebt sich nur leicht mathematisch, dass	15. Now it is easy to find mathematically that
1° nicht jeder Zahl n entspricht ein Element g (Zahl des Elemente ist beschränkt).	1st. Not every number n corresponds to an element g (the number of elements is limited).
2° Gleicher Atomzahl können verschiedene Formen entsprechen.	2nd. The same number of atoms can correspond to different forms.

16. Die Eigenschaften der Elemente sind hier als mathematische Functionen des Gewichts *g*, der Höhe *m* und des Durchschnitts *a* zu betrachten, indem diese 3 Grössen die Zahl und Lage der Pantatome völlig Bestimmen. Das Allgemeinere von diesen Grössen ist aber *a*, die Form der Basis des Atoms; also wird der allgemeine Charakter des Elementes bestimmt sein durch *a*, während die besondere Bestimmung dieses Charakters durch *m*, die Höhe, ausgedruckt wird.

17. Dadurch ist die natürlich Klassification der Elemente gegeben. Sie zerfallen in 2 Ordnungen (die Trigonoide und die Tetragonoide) nach der gegenseitigen Verbindung der Pantatome im Durchschnitt. Diese Ordnung zerfällt in Genera nach der äussern Form der Gestalt (Fig. a–m in 11 u[nd] 12). Die Species (das Element) wird bestimmt durch das Atometer *m*. Varietäten (äusserst nahe verwandte Elemente nahe gleichen Atomgewichts) entstehen durch Anwachsen der im Folgenden bestimmten Aufsätze auf dem Prisma.

18. Die genaue Bestimmung von *m* und *a* (da *g* durch Erfahrung bestimmt ist) ist nicht leicht. Die nun folgende Bestimmung ist aber jedenfalls im Ganzen richtig, da dieselben allen Anforderungen der Erfahrung genügen. In der Tafel ist immer: *A* das jetzt gebräuchliche Atomgewicht; *g* unser Atogramm und da H aus 2 Pantatomen bestehend angenommen wird, $g = 2\ A$. Wir führen keine besonderer Zeichen für diese Werthe ein, sondern benutzen die Anfangsbuchstaben die lateinischen Namen. Wenn nöthig unterscheidet man unsre Werthe leicht von den alten Equivalenten durch die Bezeichnung: Atogramm oder Hinrichs' Atomzahlen.

19. Die Genera bezeichne ich durch dem Anfangsbuchstaben ihres griechischen Namens. Dem entspricht die Formel wie der lateinische Anfangsbuchstaben und der Zahl die Species bezeichnet. Dadurch wird der Chemie eben so sehr gedient als durch die gebräuchlichen Zahlen und Symbole. Beispiel:

	Symbol		Werth]		
Genus:	Phosphoide = Φ	=	$m{\cdot}(p)$		
Species:	Phosphor = P	=	9·(7)	=	63

16. The properties of the elements are to be regarded here as mathematical functions of the weight *g*, the height *m*, and the base *a*, in which these 3 measures completely determine the number and position of the pantatoms. But the most general of these quantities is *a*, the form of the base of the atom; Thus the general character of the element will be determined by *a*, while the particular determination of this character will be expressed by *m*, the height.

17. This gives the natural classification of the elements. They divide into 2 orders (the trigonoids and the tetragonoids) according to the mutual association of the pantatoms on average. This order divides into genera according to the external form of the figure (Figs. a-m in 11 and 12). The species (the element) is determined by the atometer *m*. Varieties (very closely related elements of almost the same atomic weight) are created by merging the subsequently determined caps onto the prism.

18. The exact determination of *m* and *a* (as *g* is determined by experience) is not easy. In any case, the following determination is correct on the whole, because it satisfies all the requirements of experience. In the table is always: *A* is the atomic weight now used; *g* our atogram, and because H [i.e., hydrogen] is assumed to consist of 2 pantatoms, $g = 2\ A$. We introduce no special symbols for these values, but use the initials of the Latin name. If necessary, our values are easily distinguished from the old equivalents by the term atogram or Hinrichs's atomic numbers.

19. I designate the genera by the initial letter of its Greek name. This corresponds to the formula as the Latin initial letter and the number denoting the species. This serves chemistry as much as the ordinary numbers and symbols. Example:

	Symbol		Value		
Genus:	Phosphoid = Φ	=	$m{\cdot}(p)$		
Species:	Phosphorus = P	=	9·(7)	=	63

Verbindungen: Kα X stellt alle Verbindungen irgend eines Kaloids (Li, Na, Ka, etc) mit irgend einem Choroid (Fl, Cl, Br, I) dar.	Compounds: Kα X represents all compounds of any kaloid (Li, Na, Ka, etc.) with any choroid (Fl, Cl, Br, Jo).
20. Die bis jetzt betrachteten Atome der Elemente sind natürlich nicht in Contact; der Raum den sie beherrschen ist also grösser als das Prisma $m\cdot a$. Den ganzen Raum den ein Atome erfüllt nennen wir Kurz das Atostere (atom-Volum ist unbequem und barbarisch); bezeichnen wir es durch S, so ist offenbar $g = s\cdot S$ wo s das specifische Gewicht ist.	20. The atoms of the elements considered so far are of course not in contact; the space they dominate is thus larger than the prism $m\cdot a$. The whole space that an atom fills is called, for short, the atostere (atomic volume is inconvenient and barbaric); if we denote it by S, then obviously $g = s\cdot S$ where s is the specific gravity.
I Ordnung. Trigonoide (Metalloide).	1st Order. Trigonoids (Metalloids)

[Translator's note: in the following tables, (p) denotes a six-sided triangular raft containing p pantatoms, $/p^2/$ denotes a square raft with sides of length p, and $[i\cdot j]$ denotes a rectangular raft with sides of length i and j.]

21. Genus I. Pantoide [Pantoids]. $\Upsilon = m\cdot(1)$

	A	α	*g*	*m*	(*p*)	*s*	*S*
H	1	0.0	2	2	(1)	--	--

α ist die Abweichung meiner theor[etische] Werth von der Erfahrung, *A*.	α is the deviation of my theoretical value from the empirical value, *A*.

22. Genus II. Choroide [Chloroids]. $X = (1) + m\cdot(p)$

	A	α	*g*	*m*	(*p*)	*s*	*S*
F	19	–1.0	36	5	(7)	--	--
Cl	35.5	0.0	71	10	(7)	1.33	53.4
Br	80	–1.5	157	12	(13)	2.97	53.8
Jo	127	0.0	254	11	(23)	4.95	57.2

23. Gen. III. Phosphoide [Phosphoids]. $\Phi = m\cdot(p)$

	A	α	*g*	*m*	(*p*)	*s*	*S*
N	14	0.0	28	4	(7)	--	--
P	31	0.5	63	9	(7)	1.83	33.8
As	75	0.0	150	8	(19)	5.75	26.0
Sb	122	0.0	244	13	(19)	6.70	36.0
Bi	210	0.0	420	12	(30)	9.9	41.0

[Translator's note: In Hinrichs's 1867 paper in the *Journal of Mining*, he says "In the table of the phosphoids in my "Atomechanics" the product for As and Sb, and the atomare for Bi are mis-stated, having been written in the bustle of a printing office." Thus g should be 152 for As and 247 for Sb, and (p) for Bi should be 35.]

24. Gen. IV. Sulphoide [Sulphoids]. $\Theta = m\cdot/p^2/ = \mu\cdot[2p^2]$ (auch: Thionoide [also: Thionoids])

	A	α	*g*	*m*	$/p^2/$	*s*	*S*
O	16	0.0	32	8	2^2	--	--
S	32	0.0	64	8	$2\cdot2^2$	2.08	30.8
Se	79.4	+0.6	160	10	4^2	4.8	33.4
Te	128	0.0	256	8	$2\cdot4^2$	6.26	37.6

25. Genus V. Kaloide [Kaloids]. $K\alpha = 2(7) + 2 \cdot m \cdot 4^2$

		A	α	*g*	*m*	*s*	*S*
	Li	7	0.0	14	0	.6	23.2
	Na	23	0.0	46	1	.97	47.6
	Ka	39.1	–0.1	78	2	.865	90.0
?	In	71	0.0	142	4	7.362	19.3
	Rb	85.4	+1.6	174	5	1.52	112.2
?	Cs	183	+2.0	160	8		
?	Tl	204	–5.0	256	12	11.57	34.0

26. Genus VI. Calcoide [Calcoids]. $X\alpha = 2 \cdot 4^2 + m \cdot 2[4 \cdot 6]$

	A	α	*g*	*m*	*s*	*S*
Ca	40	0.0	80	1	1.6	50.0
Sr	87.6	+0.4	176	3	2.5	70.4
Ba	137	–1.0	272	5	4–5	54–68

27. Genus VII. Kadmoide [Kadmoids]. $K\delta = 2 \cdot 4^2 + m \cdot 2 \cdot [4.6]$ oder [or] $2 \cdot 4^2 + \mu \cdot [8 \cdot 12]$

da *m* gerade! [where *m* is even!; i.e., $m = 2\mu$]

	A	α	*g*	*m*	μ	*s*	*S*
Mg	24	0.0	48	2·[4.6]		1.74	27.6
– –							
Zn	65.2	–1.2	128	2	1	6.8–7.2	18.0–18.4
Cd	112	0.0	225	4	2	8.7	25.6
Pb	207	0.0	414	8	4	11.5	36.0

28. Genus VIII. Ferroide [Ferroids]. $\Sigma\iota = K + m \cdot 2[3 \cdot 4]$

m gerade [*m* even] $m = 2\mu$

	A	α	*g*	*m*	*K*	*s*	*S*
Al	27.4	+0.1	55	2	(7)	2.5–2.6	21–22
Fe	56	0.0	112	4	16	7.0–7.6	15–16
Rh	104.4	–0.4	208	8	16	12	17.3
Ir	198	+2.0?	400	16	16?	21	19

29. Genus IX. Molybdoide [Molybdoids]. $M\lambda = K + m \cdot 2[3 \cdot 4]$ *m* odd (except Cr)

m ungerade [*m* odd] $m = 2\mu + 1$

		A	α	*g*	*m*	*K*	*s*	*S*	
[	Cr	52.2	–0.2	104	4	8	6.0	17	]
	Mo	92	0.0	184	7	16			
	Va	137.2	–0.2	274	11	16			
	Wo	184	0.0	368	15	8	17.5	21	

30. Genus X. Cuproide [Cuproids]. $X\upsilon = K + m[5 \cdot 8]$

	A	α	*g*	*m*	*K*	*s*	*S*
Cu	63.4	+0.1	127	3	(7)?	8.85	14
Ag	108	0.0	216	5	16	10.5	25.7
Au	197	–1.0	392	9	32	19.5	20.0

31. Genus XI. Titanoide [Titanoids]. $T\tau = 2[3\cdot 4] + m[4\cdot 5]$

	A	α	g	m	s	S
C	12	0.0	24 = 2[3·4]		2.2	11.0
– –						
Si	28	0.0	56	1	2.34	23.7
Ti	50	–2.0	96	3		
Pd	106.6	+1.4	216	9	11–12	18
Pt	198	0.0	396	18	21.5	18

vielleicht auch nach [perhaps also after]

	A	α	g	m	s	S
Zr	89.6	–1.6	176	7	4.15	41.1
Sn	118	0.0	236	10	7.3	32.3
Ta	137.6	+0.4	276	12		
Th	231	–3.0	456	21		

32. Unbestimmt [Undetermined]

	A	α	g	m	s	S
Bo	11					
Be	9.3					
Hg	200					

Doch besteht Hg höchst wahrscheinlich aus Hexagonen mit folgenden Seitenlängen	However, Hg most likely consists of hexagons with the following side lengths
1 + 2 + 4 + 6 + 6 + 5 + 4 + 2 + 2	1 + 2 + 4 + 6 + 6 + 5 + 4 + 2 + 2
Also aus	That is
1 + 7 + 37 + 61 + 91 + 91 + 37 + 7 + 7 = 400	1 + 7 + 37 + 61 + 91 + 91 + 37 + 7 + 7 = 400
Pantatomen. Demnach fiele Hg zwischen $K\alpha$ und den Metalloiden; entspräche H unter den Metallen.	pantatoms. Accordingly, Hg would fall between $K\alpha$ and the metalloids; would correspond to H among the metals
33. Varietaten der Ferroide sind	33. Varieties of ferroids are

Sideroide [Sideroids], $\Sigma\delta = K + 4\cdot 2[3\cdot 4] = K + 96$

	A	α	g	K	s	S
[Cr	52.2	–0.2	104	8	6.0	17]
Mn	55	–1.0	108	12	8.07	13.5
Fe	56	0.0	112	16	7.0–7.6	15–16
Ni	58	0.0	116	20	8.6	13.5
Co	60	0.0	120	24	8.5	14.1
– –						
U	120	0.0	240			

Rhodoide, Rh, Ru	Rhodoids, Rh, Ru
Iridoide, Ir, Os	Iridoids, Ir, Os
denen Atogramme aber noch zu wenig bekannt; werden den $\Sigma\delta$ entsprechend gefunden werden. Für Co, Ni Schneider's Werthe bestätigt von v. Sommaruga; für Mn, Cr sind neue Bestimmungen geboten. Cr wahrscheinlicher Sideroid als Molybdoid.	However, too little is known about their atograms; the $\Sigma\delta$ will be found accordingly. For Co, Ni Schneider's values confirmed by von Sommaruga; for Mn, Cr new determinations are required. Cr probable sideroid as molybdoid.

[Translator's note: Erwin von Sommaruga wrote a paper on the equivalents of Co and Ni, "Ueber die Aequivalente von Kobalt und Nickel," *Wien. Akad. Sitzungsber.* **1866**, *54* (Abth. 2), 50-60; *J. Prakt. Chem.* **1867**, *100*, 106-117.]

34. Einige Atome dargestellt. H, Fl, N, O } Gase (Vol[um] gleich) Ca, Ka	34. Some atoms illustrated. H, Fl, N, O } Gases (Volume equal) Ca, Ka

---- diagrams -----

35. Die vorstehenden Zahlen enthalten alles was der Erfahrung zu entnehmen ist und eigentlich schon mehr, da die Form theoretisch bestimmt ist. Es wird eigentlich von der Erfahrung nur der Name des betreffenden Elements entlehnt, welches den verschiedenen Atom kern m entspricht. Wie die analytische Bestimmung auch unsre Atogramme und Atometer nicht als entgültig dahingestellt, sondern mögen auch einselne Modificationen erfahren. Jedenfalls aber sind sie im Wesentlichen richtig. Diese Werthe von m und a sind gewissermassen die Fundamental Constanten der materiellen Nature, die fortschreitenden Wissenschaft wird alle Erscheinungen aus diesen Zahlen errechnen, da aller Stoff Pantogen und alle Vorgänge nur mechanisch sind. Die Grundlage dieser Atomechanik geben wir hier – den Ausbau geben wir den Männern der Wissenschaft anheim.	35. The preceding numbers contain everything that can be inferred from experience, and actually more, because the form is theoretically determined. It has actually borrowed empirically only the name of the element concerned, which corresponds to the different atomic nucleus m. Because the analytic determinations of our atogram and atometer are not final, they may also undergo some modifications. In any case, they are essentially correct. These values of m and a are, so to speak, the fundamental constants of material nature; advancing science will calculate all phenomena from these numbers, because all matter is pantogen and all processes are only mechanical. The basis of this atomechanics we give here – the expansion we submit to men of science.
36. Zur Veranschaulichung der im Vorstehenden enthaltenen mechanischen oder rationellen Klassification der Elemente stelle ich sie in folgender Zeichnung dar. Das Pantogen bildet den Mittelpunkt, di Genera sind nach ihrem Generschnitt in Strahlen dieses Punktes dargestellt und die Species werden in diesen Strahlen dort verzeichnet wo der Abstand vom Mittelpunkte dem Atogramm g gleich kommt (Maassstab S einheiten in g = 1 mm). Die Symbole und Formeln der Genera, sowie die Symbole und Zahlen g der Species sind für Bezeichnung beigesetzt.	36. To illustrate the mechanical or rational classification of the elements contained in the foregoing, I present them in the following drawing. The pantogen forms the midpoint, the genera are represented by rays from this point, and the species are recorded in these rays where the distance from the center equals the atogram g (S scale units in 1 mm). The symbols and formulas of the genera, as well as the symbols and numbers g of the species are appended for designation.

37. [Hinrichs's chart]

38. Die Atometer m folgen ganz einfachen Gesetzten, die wir jetzt näher betrachten wollen um zu sehen wie die Atogramme an sich indem sie obenstehende Klassification der Elemente gestalten schon ein wichtiger Beweisgrund des Pantogens sind.	38. The atometer m follows very simple laws, which we now want to examine closer to see how the atograms in themselves by the above classification of the elements are already important evidence of pantogen.

39. Die Chloroide geben $m = 5$ (Fl) und $= 10$ (Cl) für gleiches $a = (7)$; also wie 1:2, Br, Jo representiren einfache Modificationen von a; denn Cl ist 2-2-2, Br ist 2-4-2 und Jo ist umgekehrt 4-2-4.	39. The chloroids give $m = 5$ (Fl) and $= 10$ (Cl) for the same $a = (7)$, that is 1: 2. Br, Jo represent simple modifications of a; because Cl is 2-2-2, Br is 2-4-2 and Jo is conversely 4-2-4.
40. Die Phosphoide geben $a = (7) = 2\text{-}2\text{-}2, (19) = 3\text{-}3\text{-}3$ und $30 = 4\text{-}3\text{-}4$, also consecutiv. $m = 4$ (P), 8 (As) und 12 (Bi) also = 1:2:3. Für gleiche a noch P, $4 + 5 = 9$, Sb $= 8 + 5 = 13$, constant 5.	40. The phosphoids give $a = (7) = 2\text{-}2\text{-}2, (19) = 3\text{-}3\text{-}3$ and $(30) = 4\text{-}3\text{-}4$, i.e. consecutive. $m = 4$ (P), 8 (As) and 12 (Bi) = 1: 2: 3. For the same a, P $= 4 + 5 = 9$, Sb $= 8 + 5 = 13$, constant 5.
41. Sulphoide haben alle m gleich ausgenommen Se. Die Aren [sic for Areal?] varieren regelmässig, O $\sim 2^2$, Se $\sim 4^2$ und S und Te das Doppelte $2\cdot2^2$ und $2\cdot4^2$.	41. Sulphoids all have the same m except Se. The areas vary regularly, O $\sim 2^2$, Se $\sim 4^2$ and S and Te doubled $2\cdot2^2$ and $2\cdot4^2$.
42. Kaloide; m für Li : Na : Ka : Rb sind 0 : 1 : 2 : 5. Für die noch zweifelhaften In : Cs : Tl = 4 : 8 : 12 = 1 : 2 : 3 so dass dieselben füglich als $4\cdot4^2 = 8^2$ Basis inzwischen wären mit den Atometern $\mu = 1, 2, 3$. Wir nennen sie Thalloide, $\Theta\lambda = 2\ (7) + 2\ \mu\ 8^2$. Dem entsprechen ihre Eigenschaften.	42. Kaloids; m for Li : Na : Ka : Rb are 0 : 1 : 2 : 5. For the still doubtful In : Cs : Tl = 4 : 8 : 12 = 1 : 2 : 3 so that the same would be acceptable as a $4\cdot4^2 = 8^2$ base with the atometers $\mu = 1, 2, 3$. We call them thalloids, $\Theta\lambda = 2\ (7) + 2\ \mu\ 8^2$. This corresponds to their properties.
43. Calcoide bilden $m = 1, 3, 5$, mit constanter Differenz 2.	43. Calcoids form $m = 1, 3, 5$, with constant difference 2.
44. Kadmoide haben die geraden $m = 2, 4, 8$, so dass wahrscheinlich $\mathrm{K}\delta = 2\cdot4^2 + \mu[8\cdot12]$ wo $\mu = 1, 2, 4$.	44. Kadmoids have even $m = 2, 4, 8$, so that probably $\mathrm{K}\delta = 2\cdot4^2 + \mu\ [8\cdot12]$ where $\mu = 1, 2, 4$.
45. Die Ferroide geben die Meter Al : Fe : Rh : Ir $= 2 : 4 : 8 : 16 = 1 : 2 : 4 : 8 = 2^0 : 2^1 : 2^2 : 2^3$ oder successiv Verdopplung; wie μ der Kadmoide, wie Cl [und] Fl, As und N.	45. The ferroids give the measures Al : Fe : Rh : Ir $= 2 : 4 : 8 : 16 = 1 : 2 : 4 : 8 = 2^0 : 2^1 : 2^2 : 2^3$ or successive doubling; like μ for the Kadmoids, like Cl [and] Fl, As and N.
46. Die ungeraden Werthe m der Molybdoide sind 7 : 11 : 15 zeigen also die constante Differenz 4 welche auch Glied der Ferroide ist.	46. The odd values of the molybdoids are 7: 11: 15, so they show the constant difference 4, which is also a [mathematical] term for the ferroids.
47. Die Cuproide geben ähnliche 3 : 5 : 9 die Differenzen 2 u[nd] $4 = 2\cdot2$. Die Molybdenoide und Cuproide sind also, wie es auch das gleiche Atomare [3.4] erheischt, nur Seitenzweige der Ferroide.	47. Similarly The cuproids give 3 : 5 : 9 the differences 2 and $4 = 2\cdot2$. The molybdenoids and cuproids are thus, as the same atomic area [3.4] requires, only side branches of the ferroids.
48. Die Titanoide haben die Atometer $1 : 3 : 9 : 18 = 3^0 : 3^1 : 3^2 : 2\cdot3^2$ oder eine änliche Beziehung wie die der Ferroide.	48. The titanoids have the atometers $1 : 3 : 9 : 18 = 3^0 : 3^1 : 3^2 : 2\cdot3^2$ or a similar relationship as that of the ferroids.
49. Ganz besonders wichtig ist noch die gegenseitige Beziehung der 3 Haupt Genera mit rectangulärer Basis, nämlich die Ferroide [3·4] die Titanoide [5·4] und die Kadmoid [6·4] oder [12·8]. Dies ist ausgedrückt durch den fast gleicher Werth des Atometers Atogramms g für die successivter Glieder dieser Genera, nämlich	49. Especially important is the mutual relation of the 3 main genera with a rectangular base, namely the ferroids [3·4] the titanoids [5·4] and the kadmoids [6·4] or [12·8]. This is expressed by the almost equal value of the atometer [and] atogram g for the successive members of these genera, viz.

						Sauerstoffverbindung [Oxygen compound]	
Kadmoide		Mg 48	Zn 128	Cd 224	Pb 414	$K\delta\,\Theta$	1 : 1
Ferroide		Al 55	Fe 112	Rh 208	Ir 400	$\Sigma\iota_2\,\Theta_3$	1 : 1½
Titanoide	C 24	Si 56	Ti 96	Pd 216	Pt 396	$T\iota\,\Theta_2$	1 : 2

Jeder Chemiker wird die vollkommene Harmonie dieser Verhältnisse leicht werden ausführen können. Bo entspricht wahrscheinlich dem C unter den $M\lambda$. Be auch die $\Sigma\iota$.

Any chemist will easily be able to explain the perfect harmony of these relationships. Bo probably corresponds to C [i.e., carbon] under the $M\lambda$. Be also [probably with] the $\Sigma\iota$.

50. Diese einfachen Atometer-Beziehungen wären an sich wichtige Stützen für die Richtigkeit unserer Atom formeln; Sie sind aber ein positiver Beweis, wenn man bedenkt dass alle die in einem Genus vereinten Elemente die durch diese Atometer-Beziehungen verknüpft sind, höchst natürliche Gruppen darstellen, Gruppen der die besten bisher versuchten Klassificationen in sich schliessen.

50. These simple atometer relationships would in themselves be useful supports for the correctness of our atomic formulas; but they are positive proof, considering that all the elements united in one genus are linked by these atometer relationships, representing the highest natural groups, groups that contain the best classifications tried so far.

51. Schon hier wird eine hoch bedeutsame Analogie sich aufdrängen: nämlich die zwischen den bekannten Reihen organischer Verbindungen und unsern Genera. So ist die Formel der monatomischen Alkohole = $C^nH^{2n+2}O$ = $H_2O + n[CH_2]$ ganz von die Form unserer Chloroide $X = (1) + m\ (p)$ oder Kaloide $K\alpha = 2(7) + m[2{\cdot}4^2]$. Die Eigenschaften sind in beiderlei Reihen ähnlich bestimmbar.

51. Already here a highly significant analogy will arise: namely, that between the known series of organic compounds and our genera. Thus, the formula of monatomic alcohols = $C^nH^{2n+2}O = C^nH^{2n} = H_2O + n[CH_2]$ is entirely of the form of our chloroids $X = (1) + m\ (p)$ or kaloids $K\alpha = 2\ (7) + m\ [2{\cdot}4^2]$. The properties are similarly determinable in both series.

52. Allgemein mathematische Untersuchungen zeigen dass nicht aus jeder Zahl *n* Pantatome eine geschlossene prismatische Atomgestalt sich bilden lässt (§.15). Denn in $g = m{\cdot}a$ muss erstens das Atomare *a* eine geschlossene Figur sein, denen Pantatomare also schrittweise wächst und *m* kann auch nur regelmässig nach bestimmten Gesetzen fortschritten. Siehe Beispiele §.11 u. §§.38-50.

52. General mathematical investigations show that not every number *n* of pantatoms allows a closed prismatic atomic form to be built (§15). For in $g = m{\cdot}a$, first of all, the atomare *a* must be a closed figure, to which pantatomares thus grow gradually, and *m* can only progress regularly according to certain laws. See examples §.11 and §§.38-50.

53. Daraus folgt aber ferner dass nahezu gleiche Werthe von *g* verschiedenen Formen entsprechen können, d[as] h[eisst] nahe gleiche *g* geben Species verschiedene Genera. Dies zeigt unsre Karte §.37 recht deutlich. Beispiele:

53. It follows, however, that nearly equal values of *g* can correspond to different forms; that is, near equal *g* give species of different genera. Our chart § 37 shows this quite clearly. Example:

	Θ	Φ	X	Mittel [Average]	Kα	Xα, Kδ	Σι	Tτ	Mittel [Average]
C 24	O 32	N 28	Fl 36	30	Li 14			C 24	14-24
	S 64	P 63	Cl 71	66	Na 46	Mg 48	Al 55	Si 56	51
	Se 160	As 150	Br 157	156	Ka 78	Ca 80			79
	Te 256	Sb 244	Io 254	251		Zn 128	Fe 112	Ti 96	112
		Bi		420		Cd 224	Rh 208	Pd 216	216
						Pb 414	Ir 400	Pt 396	403

[54.] Man ersieht auch dass die Gruppen abwechselnd Metalle und Metalloide umfassen; so dass die bekannten Elemente in unsrer Karte in Spiralgeraden auf einander folgen. Siehe in 37 der Linien H-Li-C-O-N-Fl-Na-Mg-Al-Si-S-P-Cl-Ka-Ca-Ti und dann in entgegengesetzte Richtung Ti-Fe-Zn-In-Br-As-Se-Pd-Rh-Cd-Cs-Jo-Sb-Te. Da unsrere Spire [sic] umfasst nahezu alle Elemente die allgemeinere Bedeutung haben.	[54.] One sees also that the groups alternately include metals and metalloids; so that the known elements in our chart follow one another in spiral lines. See in 37 the lines H-Li-C-O-N-Fl-Na-Mg-Al-Si-S-P-Cl-Ka-Ca-Ti and then in the opposite direction Ti-Fe-Zn-In-Br-As-Se-Pd-Rh-Cd-Cs-Jo-Sb-Te. So our spiral includes almost all elements of more general significance.
55. Je kleiner überhaupt *g*, je näher das Element dem Pantogen steht, um so bildungsfähiger muss es sein. Daher sind C mit H, N und O aus dem innersten Kreise die Hauptbestandtheile aller organischen Körper (organogene) So auch die Elemente bis *g* gegen 100 (Fe = 112) die hauptsächlichsten Körper der unorganischen Welt – nicht nur auf Erden, sondern auch in den Meteoriten und Sternen, wie die Spectralanalyse zeigt.	55. The smaller the *g*, the closer the element is to pantogen, [and] the more capable of development it must be. Therefore, C with H, N and O from the innermost circle [of the chart] are the main constituents of all organic bodies (organogenic). So the elements up to *g* around 100 (Fe = 112) are the most important bodies of the inorganic world – not only on Earth, but also in the meteorites and stars, as spectral analysis shows.
56. Nach diesen allgemeinen Betrachtungen schreiben wir zur speciellen Uebersichtung der Eigenschaften der Elemente um endgültig zu entscheiden, ob unsre Annahme des Pantogens zur Erklärung der Elemente ausreicht und daher die Frage nach der Constitution der Materie löst. Wir betrachten am zweckmässigsten zuerst die chemische Eigenschaften oder eigentlich die Verbindungsweisen an sich. Hiernach folge die Untersuchung der physikalischen Eigenschaften und schliesslich die durch die Constitution gegebenen Morphologischen Eigenschaften (die Krystallformen). Die strenge Sonderung der Elemente und ihre Verbindungen wäre unzweckmässig; wir werden daher beide miteinander betrachten.	56. After these general considerations, we set down a special overview of the properties of the elements in order to finally decide whether our assumption of the pantogen is sufficient to explain the elements and therefore solve the question of the constitution of matter. We best consider first the chemical properties or actually the bonds per se. This is followed by the examination of the physical properties and finally the morphological properties (the crystal forms) given by the constitution. The strict separation of the elements and their compounds would be inappropriate; we will therefore consider both of them together.

Zweiter Abschnitt. Chemische Eigenschaften der Elemente.

57. Die chemische Verbindung zweier Atome A und B als mechanische Erscheinung betrachtet kann nur in einer nebeneinander Lagerung der Atome (juxtaposition) AB bestehen. So auch wären *m* Atome A sich mit *n* Atomen B verbinden. Um das Nähere zu erforschen wollen wir hier das im nächsten Abschnitt erörterte Gesetz der Gleichheit der Atostere der Element in Gasform annehmen, worauf wir auch in §.34 schon Bezug nahmen.

58. Wenn wir nun mit den heutigen Chemikern annehmen, dass je 2 Atome in Gasform ein Molekül bilden, so wäre nebenstehende Zeichnung wohl eine Darstellung eines solchen Moleküls. Die Atomen A haben ihrer Schwerpunkt in C; die Ebene durch C senkrecht zu der sei Verbindung Achse theilt das Molekül-Volumen in 2 gleich Theile. Dies wäre der Wasserstoff-Typus der modernen Chemie.

59. Für das eine A liesse sich ein Atom B eines demselben Genus angehörenden andern Elementes substitutiren, ohne irgend etwas zu andern. Die chemische Verbindung AB bestünde also aus 2 Volumen, ohne Condensation. Dies ist der Chlorwasserstofftypus der modernen Chemie.

60. Wenn 2 B sich mit A verbinden sind 2 Fälle denkbar. Entweder bilden sie 3 Atome eine gerade Linie (1 [und] 1‘) oder nicht (2); der letztere Fall giebt aber immer ein Dreieck.

Wären die Atome in einer geraden Linie so müssten sie durch die geringste Veranlassung (Wärmeschwingung Licht, Electricität etc.) für einen Augenblick aus derselben gerissen werden. Dann würde aber die gegenseitig Anziehen die drei Atome ein Dreieck BAB‘; und zwar ein gleichschenklicher da beide B mechanisch völlig gleich sind, also die Bezug auf A gleiche Lage haben müssen. A ist daher der Scheitel, B B‘ der Grundlinie des Dreiecks.

61. Sei nun C der Schwerpunkt des Dreiecks (also AC = 2 CO); dann ist das Gewicht BB‘ in Bezug auf die Axe EF, gleich dem Gewichte B in A‘ wenn CA = 2 CO also CA‘ = CA. Die Ebene EF theilt den Raum des zusammengesetzten Moleküls in 2 Theile. Da nun das System A,2B equivalent ist dem A,

Second Section. Chemical Properties of the Elements.

57. The chemical bonding between two atoms A and B, viewed as a mechanical phenomenon, can only consist of the side-by-side arrangement (juxtaposition) of atoms, AB. So also would *m* atoms of A combine with *n* atoms of B. In order to explore the details, we want to adopt the law of equality of the atostere of the elements in the gaseous form discussed in the next section, which we also referred to in §.34.

58. If we now assume with today’s chemists that every 2 atoms form a molecule in the gaseous form, the drawing opposite would be a representation of such a molecule. The atoms A have their center of gravity at C; the plane through C perpendicular to the connection axis divides the molecular volume into 2 equal parts. This would be the hydrogen type of modern chemistry.

59. An atom B of a different element belonging to the same genus could be substituted for A without changing anything. The chemical compound AB would therefore consist of 2 volumes, without condensation. This is the hydrogen chloride type of modern chemistry.

60. If 2 B connect to A, 2 cases are conceivable. Either they form 3 atoms in a straight line (1 [and] 1') or not (2); the latter case always gives a triangle.

If the atoms were in a straight line, they would have to be torn out of it for a moment by the slightest reason (heat vibration, light, electricity, etc.). Then, however, the mutual attraction of the three atoms would form a triangle BAB'; namely an isosceles because both B are mechanically completely the same, that is, they must have the same position with respect to A. A is therefore the vertex, B B' the baseline of the triangle.

61. Let C be the center of gravity of the triangle (so AC = 2 CO); then the weight BB‘ with respect to the axis EF is equal to the weight B in A‘ if CA = 2 CO thus CA' = CA. The level EF divides the space of the compound molecule into two parts. Thus the system A,2B is now equivalent to A,A‘, but

A‘, dies aber nach §.59, aus gleichen Volumen besteht, es folgt. In Verbindungen A,2B verdichten sich die 2 Volumina B zu einem, welcher ohne weitere Verdichtung mit diese Volum A zu 2 Volumen zusammentritt. Die Verdichtung ist also 2/3; die graphische Darstellung das Dreieck ABB. Dies ist der Gerhardt’schen Typus Wasser HHO.

62. Für 2 A und 1 B würde ganz dasselbe gelten; dies sehen wir beispielweise am Stickstoffsoxidul N_2O und der Untersalpetersäure NO_2. Im ersten verdichten sich die 2N zu 1 Volum, im letztern die 2O. Dieser wohl bewiesene Fall zeigt deutlich, dass das Gesetz ein universeller ist, unabhängig von den „besondern“ Eigenschaften den sich verbindenden Element. So auch in Wasser verdichten sich 2 Vol[umen] H zu einem Volum das mit dem O zusammentritt.

63. Diese Condensation hat durchaus nichts Auffälliger. Wissen wir doch, dass in 1 Vol[um] Cl 35 ½ mal so viele Pantatome sind, als in dem gleichen Volum Wasserstoff u[nd] s[o] w[eiter]. So können dann auch leicht 2 H auf den Raum (Atostere) eines H zusammengedrängt werden. Ebenso 3-4 etc. und allgemein *n* H, so wohl als *n* A und m B.

64. Diese ganze Schlussweise, sowohl was Stellung als auch was der Raumfüllung betrifft, kann leicht auf 1 A und *n* B ausgedehnt werden, und noch ferne auf *n* A und *m* B. In A mit 3 B müssen die 3 B, da sie gegenseitig gleich sind, auch zu A gegenseitig ganz gleiche Stellung haben; sie bilden also ein gleichseitiger Dreieck, und A steht gerade über dem Schwerpunkt dieses Dreiecks. Dieser Schwerpunkt representiert gewissermaassen einen neuen Atom B‘ und dieser ist mit A ohne Verdichtung verbunden. Die 3 Volumina B auf 1 reducirt sind zu dem 1 Volum A gefugt, so dass 2 Volum der Verbindung resultieren. Dies wäre der Ammoniak Typus mit Bestimmung der gegenseitigen Lage der Atome, welche Bestimmung der Typenlehre fehlt. Ebenso wie auch der Nachweis der Wie der Condensation erst durch dieser Theorie gegeben werden konnte. Im Allgemeinen:

65. Wenn *m* Atome A sich mit *n* Atomen B zu dem A^mB^n verbinden, so geschieht es, indem die m A sich auf 1 Vol[um] zusammenziehen, ebenso die n B auf 1 Volum, welche sich nun

according to §.59, it follows that it consists of the same volume. In compounds A,2B, the 2 volumes of B compress to one, which combine these volumes A to 2 volumes without further compression. The compression is therefore 2/3; the graphical representation of the triangle ABB. This is the Gerhardt water type HHO.

62. The same would apply to 2 A and 1 B; we can see this, for example, in nitrogen oxide N_2O and sub-nitric acid NO_2. In the first the 2N compress to 1 volume, in the latter the 2O. This well-proven case clearly shows that the law is universal, regardless of the "special" properties of the connecting element. So too in water, 2 volumes of H condense to a volume that combines with O.

63. This condensation is nothing particularly striking. We know that there are 35½ times as many pantatoms in 1 volume of Cl as there are hydrogen in the same volume, and so on. In this way, 2 H can easily be pushed together into the space (atostere) of one H. Likewise 3-4 etc. and generally *n* H, as well as *n* A and *m* B.

64. This whole procedure, both in position and in terms of space filling, can easily be extended to 1 A and *n* B, and still further to *n* A and *m* B. In A with 3 B the 3 B, because they are equal to one another, also have mutually identical positions with respect to A; so they form an equilateral triangle, and A is just above the center of gravity of this triangle. This center represents, so to speak, a new atom B' and this is connected to A without compression. The 3 volumes of B reduced to 1 are added to the 1 volume of A, so that 2 volumes of the compound result. This would be the ammonia type with determination of the mutual position of the atoms, a determination that the type theory lacks. Likewise, the proof of how condensation [occurs] could only be given by this theory. In general:

65. If *m* atoms A combine with *n* atoms B to form the A^mB^n, so it happens, that the *m* A contract to 1 volume, as well as the *n* B to 1 volume, which are now next to each other, as

neben einander, lagern wie im Molekül eines Gases, so dass die Ebene der Atome A derjenigen von B parallel ist und die Verbindungslinie der Schwerpunkt auf beiden Ebenen sinkrecht steht. Im resultierende Condensation $c = s/S = 2/(n + m)$ wo s das Volum der Verbindung, S die Summe der noch unverbundenen Atostere ist.

66. Wenn $m = 1$, und $n = 1, 2, 3, 4$, so erhalten wir die gewöhnlichen Typen der modernen Chemie. Ich gebe nebenstehend eine graphische Darstellung derselben, welche sowohl Anordnung (Constitution) als auch Volum-Verhältnis und Condensationsgrad zeigt; ferner die rationellen Symbole AB^n und endlich noch die gebräuchlichen Typen-Symbole.

Wir werden Gelegenheit haben diese Gesetze durch reichlichen Erfahrungs dahin zu belegen.

67. Es ist jedoch einseitig, diese als die einzigen Typen zu betrachten. 2 A mit 3 B, 2 A mit 5 B etc. sind ebenfalls Typen. Als Beispiel führen wir nur an N_2O_3, N_2O_5, Cl_2O_5, Cl_2O_7 etc., sowie die vielen Sesquiverbindungen der Ferroide.

68. In seiner Allgemeinheit gilt dieses Gesetz nur für den gasförmigen Zustand, da ist auf die Gleichheit der Atostere in gasform beruht. Im Folgenden machen wir diese Gleichheit als eine Folge der gegenseitig grossen Abständen der Atome in Bezug auf ihr Atometer *m* und Atomare *a* kennenlernen. Für den fest-flüssigen Zustand sind diese Grösser sehr merklich im Vergleich zum Atostere; also werden für diese Zustände obige Gesetze nur in Bezug auf die allgemein-gültige Anlagerung der Theile gelten, nicht aber in Übersicht auf Volumen oder Condensation. In Bezug auf letztere ergiebt sich leicht, dass die Condensation um so mehr dem obigen Gesetz für Gase entsprecht, je grösser das Prisma A im Vergleich zu den damit verbundenen *n* Prismen B ist.

Zum Beispiel ΦX_3 sollte geben $c = ½ = 0.50$. Man findet aber für

$PCl_3 = 0.88$, $AsCl_3 = 0.88$, $SbCl_3 = 0.87$, $BiCl_3 = 0.68$, eine Mittel 0.83

$PBr_3 = 0.94$, $AsBr_3 = 0.91$, ---, $BiBr_3 = 0.80$, eine Mittel 0.91

69. Die Substitutions-Erscheinungen bestehen

in the molecule of a gas, so that the level of atoms A is parallel to that of B and that the connecting line of gravity is perpendicular to both levels. In the resulting condensation $c = s/S = 2/(n + m)$ where *s* is the volume of the compound, [and] *S* is the sum of the still unconnected atosteres.

66. If $m = 1$, and $n = 1, 2, 3, 4$, we get the common types of modern chemistry. I give a graphical representation of the same on the left, which shows the arrangement as well as the volume ratio and degree of condensation; also the rational symbols AB^n and finally the common type symbols.

We will have the opportunity to prove these laws through extensive experience.

67. However, it is one-sided to consider these as the only types. 2 A with 3 B, 2 A with 5 B etc. are also types. For example, we list only N_2O_3, N_2O_5, Cl_2O_5, Cl_2O_7 etc., as well as the many sesqui-compounds of the ferroids.

68. In general, this law applies only to the gaseous state, because it is based on the equality of the atostere in gaseous form. In the following we get to know this equality as a consequence of the large distances between the atoms in relation to their atometer *m* and atomare *a*. For the solid-liquid state, these sizes are very noticeable compared to the atostere; so the above laws will apply only to these conditions with regard to the generally applicable attachment of the parts, but not with regard to volume or condensation. With regard to the latter, it is easy to see that the larger the prism A is in comparison to the associated *n* prisms B, the more the condensation conforms to the above law for gases.

For example ΦX_3 should give $c = ½ = 0.50$. But one finds for

$PCl_3 = 0.88$, $AsCl_3 = 0.88$, $SbCl_3 = 0.87$, $BiCl_3 = 0.68$, an average [of] 0.83

$PBr_3 = 0.94$, $AsBr_3 = 0.91$, ---, $BiBr_3 = 0.80$, an average [of] 0.91

69. The phenomena of substitution exist in

zu der Typenlehre da diese aber in unsrer Theorie inbegriffen ist, so folgt dass auch die Substitutionserscheinungen unsre Theorie bestätigen. Wir werden auf Volum und Krystall Verhältnisse ausführlich zurückkommen, und darin ganz besondere Bestätigungen der Verdichtung und Constitution finden. So auch in der jetzt folgenden Abteilung der Gerhardt'schen Typen selbst in Bezug auf Atomicität.

Pantoid-Verbindungen

70. Chloropantoide $X\Upsilon$, oder zu gleichen Atomen. Da $X = (1) + m(p)$ ein einzelner Pantatom als Scheitel hat, ist dieses der Punkt, grösster Anziehung, oder Kurzweg ein chemischer Pol. Daferner die Atome mit der Längsrichtung parallel stehen, so kann jedes X also, nur ein $\Upsilon = 2(1)$ aufnehmen, wie obige Formel ausdrückt. Die einfache Anlegung von einem Atom X an einem Atom $\Upsilon = H$ kann offenbar keine Volumänderung hervorbringen; also 1 Vol[um] X + 1 Vol[um] Υ = 2 Vol[um] $X\Upsilon$. Dies der Chlorwasserstoff-Typens der modernen Chemie. Beispiele, FlH, ClH, BrH, JoH.

71. Phosphopantoide $\Phi\Upsilon_3$. Die Endfläche ist ein regelmässiges Sechseck (Bi sehr nahe). Also 3 gleiche Anziehungs-maxima, die Punkte X in der Figur. Die 3 H werden aber keine grössre Breite (Atomare) einnehmen, als der eine Atom Φ. Folglich 3 H-Volume verdichten sich auf 1 Vol[um], und verbinden sich dann ohne weitere Verdichtung mit Φ. Dies ist der Ammoniak-Typus der modernen Chemie. NH_3, PH_3.

Verbindungen in andern Verhältnissen sind natürlich nicht ausgeschlossen, aber doch nicht es beständig wie der typisch $\Phi\Upsilon_3$.

72. Sulphopantoide, $\Theta\Upsilon_2$. Da $\Theta = m/p^2/$ oder $= \mu[2 \cdot p^2]$ so ist $O = 8 \cdot 2^2$ oder auch $= 4 \cdot [2 \cdot 2^2]$. Die Entscheidung lässt sich aus dem Gewicht natürlich nicht ableiten. Beide Annahmen geben 2 chemische Pole, B aber deutlicher, als A. Die Formel deutet an, dass jedes 2^2 eine ganz gesonderte Stellung hat, indem also der Abstand beider 2^2 grösser oder kleiner ist, als die Dimension jeder 2^2. Wäre A wichtig, so müsste $\Theta\Upsilon$ eben so häufig sein wie $\Theta\Upsilon_2$. Da aber letztere fast ausschliesslich beobachtet ist – der Wasser Typus der modernen Chemie -

relation to type theory, but since this is included in our theory, it follows that the phenomena of substitution also confirm our theory. We will come back to volume and crystal conditions in detail, and find very special confirmations of the compression and constitution. So also in the following section of Gerhardt's types themselves in terms of atomicity.

Pantoid [Hydrogen] Compounds

70. Chloropantoids [hydrogen chloroids] $X\Upsilon$, or equivalent atoms. Because $X = (1) + m(p)$ has a single pantatom as the apex, this is the point, greatest attraction, or short path, of a chemical pole. Furthermore, because the atoms are parallel with the longitudinal direction, each X can take up only one $\Upsilon = 2(1)$, as the above formula espresses. The simple application of an atom X to an atom $\Upsilon = H$ obviously cannot produce a volume change; thus 1 volume X + 1 volume Υ = 2 volumes $X\Upsilon$. This is the hydrogen chloride type of modern chemistry. Examples, FlH, ClH, BrH, JoH.

71. Phosphopantoids [hydrogen phosphoids] $\Phi\Upsilon_3$. The end face is a regular hexagon (Bi very close). So [there are] 3 equal maxima of attraction, the points X in the figure. However, the 3 H will not have a greater breadth (atomare) than the one atom Φ. Consequently, 3 H volumes compress to 1 volume, and then combine with Φ without further compression. This is the ammonia type of modern chemistry. NH_3, PH_3.

Compounds in other ratios are of course not excluded, but [are] not as stable as the typical $\Phi\Upsilon_3$.

72. Sulphopantoids [hydrogen sulfoids], $\Theta\Upsilon_2$. Because $\Theta = m\ /p_2/$ or $= \mu\ [2 \cdot p^2]$ then $O = 8 \cdot 2^2$ or also $= 4 \cdot [2 \cdot 2^2]$. The decision cannot, of course, be derived from the weight. Both assumptions give 2 chemical poles, but B more clearly than A. The formula indicates that each 2^2 has a very special position, i.e. the distance between the 2^2 is larger or smaller than the dimension of each 2^2. If A were important, $\Theta\Upsilon$ should be just as common as $\Theta\Upsilon_2$. But because the latter is observed almost exclusively – the water type of

so muss also B richtig sein; dies wird sich im Folgenden in den physikalischen Eigenschaften vollkommen bestätigen. So stimmt z[um] B[eispiel] das Refractions-equivalent genau mit B, durchaus nicht mit A. Die Allotropie des O ist ebenfalls nur in B erklärlich. Hier sind denn wie diesen 2 ϒ auf den Querschnitt des Θ zusammengedrängt, ohne das ihre Länge irgendwie hätte geändert werden können.

73. Titanopantoide, $\mathrm{Ti}\Upsilon_4$. C = 2[3·4]. Basis [3·4] giebt gewissermaassen ein Dreieck von 3 Pantatomen 4 mal, wie B anzeigt. Daher die Verbindung CH_4 und wie vorhin der Condensation 2/5 = 2/(1+4). Der Kohlenwasserstoff Typus.

74. Veranschaulichung des Typen, sowohl in ihrer Zusammensetzung als in den Condensations-Verhältnissen ist nebenstehend versucht. Im gleichen Quadrate bezeichnen gleiche Volumen.

Zum Zweck der kurzen Darstellung von Verbindungen sowohl an sich, als namentlich in Bezug auf Krystallform, hat die Anwendung der verticalen Stellung grosse Vorzüge. Wir werden dieselbe daher im Folgenden fast ausschliesslich benutzen. Der Kurze wegen werden wir H einfach durch ein verticales Comma ′ bezeichnen. Demnach erscheinen der Typen, perspectivisch

′ ′ ′ ′ ′ ′ ′ ′
X Θ ′Φ′ ′Ti′ oder ′C′.

75. Es scheint mir durch Vorstehendes (§.§.70-74) in Verbindung mit den Früher entwickelten Gesetzen sei nicht nur die Typenlehre auf eine rationelle, mechanischen Basis zurück geführt und erklärt, sondern auch wesentlich näher bestimmt; statt blos einer Ausdruck der Reactionen zu geben, ist jetzt durch meine Symbole eine perspectivisch Darstellung der wirklichen Constitution gegeben. Darauf fusst meine Krystall-lehre und darauf können wir auch Einsicht in der wirkliche Constitution der organischen Reihen erlangen. Dies ist jetzt zu thun.

76. Der typische Kohlenwasserstoff C'''' ist gesättigt; *n* Atome können sich eben so wenig verbinden mit von irgend einer andern Verbindung.

modern chemistry – B must be correct; this will be fully confirmed in the physical properties below. For example, the refraction equivalent matches B, not at all A. The allotropy of O is also understandable only by B. Here, 2 ϒ are squeezed like this onto the profile of the Θ, without which their length could have been changed in any way.

73. Titanopantoids [hydrogen titanoids], $\mathrm{Ti}\Upsilon_4$. C = 2[3·4]. The base [3·4] gives to a certain extent 4 times a triangle of 3 pantatoms, as B indicates. Hence the compound CH_4 and as before the condensation 2/5 = 2/(1 + 4). The hydrocarbon type.

74. An illustration of the type, both in its composition and in the condensation ratios, is attempted below. Equal squares denote equal volumes.

For the purpose of the short description of compounds, both as such and especially in relation to crystalline form, the application of the vertical position has great advantages. Therefore, we will use it almost exclusively in the following. For the sake of brevity, we will simply denote H by a vertical comma ′. Accordingly, the types appear, in perspective

′ ′ ′ ′ ′ ′ ′ ′
X Θ ′Φ′ ′Ti′ or ′C′.

75. It seems to me from the above (§.§.70-74) in connection with the earlier developed laws that not only the type theory can be traced and explained on a rational, mechanical basis, but also much more precisely determined; instead of just expressing the reactions, my symbols now give a perspective representation of the real constitution. My crystal theory is based on this and we can also gain insight into the real constitution of the organic series. This is to be done now.

76. The typical hydrocarbon C'''' is saturated; *n* atoms can cannot bind with any other compound.

77. Mehrerer C-Atome können sich aber parallel nebeneinander zu einer Riehe zusammenstellen in der beigezeichneten Weise. Dem Atom a) = CH_4 fügt sich noch 1 C bei, der 2 H rechts dienen als Verbindungsglied, als Kette der beiden; siehe a^1). Das letztere C_2H_4 kann noch offenbar 2 H aufnehmen; daraus entsteht b = 2C6H = C_2H_6. Hieraus wieder c = C_3H_8 und wie leicht ersichtlich allgemeine, C_nH_{2n+2} welches ich Υ_n^o (Hydrocarbon, o -atomisch) bezeichne.	77. Several C atoms can, however, assemble parallel to each other to form a row in the manner shown. 1 C can be added to the atom a) = CH_4, the 2 H on the right serve as a link, as a chain of the two; see a^1). The latter C_2H_4 can apparently still take up 2 H; this results in b = 2C6H = C_2H_6. From this again c = C_3H_8 and as can be seen in general, C_nH_{2n+2} which I call Υ_n^o (hydrocarbon, o - atomic).

[Translator's note: paragraphs 78-87 give Hinrichs's theory of organic chemistry; mainly based on the idea that the hydrogen atoms are directly involved in the formation of C-C (and also C-X) bonds]

88. Es könnten zwar auch 6 Atome auf einem N Platz finden, besser aber schön 4, die mit *o* bezeichneten. Dies letzten giebt Ammonium, Am = NH_4 und seine Derivative. Die Verbindungen derselben, namentlich die Haloide, ergeben sich leicht (siehe bei gefügte) perspectivische Ansicht. NX bildet die Axe, 4 H eine Equator-Ebene. Es ist der Prototyp der Spiralle, u[nd] wie diese tessular.	88. There could also be 6 atoms on one N site, but better 4, which are marked with *o*. The latter gives ammonium, Am = NH_4 and its derivatives. The compounds of the same, namely the haloids, arising from a simple perspective view (see attached). NX forms the axis, 4 H an equatorial plane. It is the prototype of the spiral and like this cubic.
89. Ammonium dargestellt und mit Kalium vergleichen.	89. Ammonium shown and compared with potassium.
90. Cyan dargestellt und mit den Choroiden vergleichen.	90. Cyanide shown and compared with chloride.
91. Nachdem der Hydrogen oder Pantoid-Verbindungen mit einiger Ausführlichkeit betrachtet sind, dürfen wir im Folgenden uns einer kürzer fassen in Bezug auf die X, Φ, Θ-Verbindungen.	91. Having considered the hydrogen or pantoid compounds in some detail, in the following let us take a brief look at the X, Φ, [and] Θ compounds.
Chloroide Verbindungen, etc.	**Chloroid Compounds, etc.**
92. Da der X = (1) + *m* (*p*) mit (1) enden, so werden ihrer Verbindungen sich XX, ΘX_2, ΦX_3, $T\iota X_4$ schreiben. Die Volumina in Gasform folgen den oft erwarteten Gesetzen. Im fest-flüssigen Zustande müssen wir aber erinnern, dass mit dem Atomare X im Vergleich zum Radical R in RX_n das resultirende Atostere wachsen muss (§. 68).	92. Because the X = (1) + *m* (*p*) ends with (1), [we] will write their compounds thus XX, ΘX_2, ΦX_3, $T\iota X_4$. The volumes in gaseous form follow the often expected laws. In the solid-liquid state, however, we must remember that with [an increase in] the atomare X, just like the radical R in RX_n, the resulting atostere must grow (§ 68).
93. $X_2\Theta$, $X_2\Theta_3$ mit (a) als Ort für O der Basis; (b) für die beiden Θ in $X_2\Theta_5$.	93. $X_2\Theta$, $X_2\Theta_3$ with (a) as the location for O of the base; (b) for the two Θ in $X_2\Theta_5$.
94. ΦX_3 dargestellt das mittleren Sechseck ist Φ.	94. ΦX_3 depicted the middle hexagon is Φ.
95.Titanochloroide, TiX_4.	95.Titanochloroids, TiX_4.

96. Ferrochloroide, $\Sigma\iota X_2$, $\Sigma\iota X_3$, $\Sigma\iota X_4$.	96.Ferrochloroids, $\Sigma\iota X_2$, $\Sigma\iota X_3$, $\Sigma\iota X_4$.
97. Calcochloroide, $X\alpha X_2$.	97.Calcochloroids, $X\alpha X_2$.
98. Kalochlorode, KαX.	98.Kalochloroids, KαX.
99. Wie in den organischen Reihen, so ist hier die Endung der Atome von Einfluss. So ist Kα durch die Endung monatomisch in Bezug auf X.	99. As in the organic series, the terminus of the atoms is of influence here. Thus Kα is monatomic with respect to X.
100. Figur [Figure; A schematic diagram of Hinrichs's chart]	
101. In der nebenstehenden Figur ist das Hauptresultat der Verbindungsverhaltnissen zusammengestellt. Die Zahl giebt an, wie viele Atome X (innerer Kreis) oder Θ (äusserer) sich mit eineres Atom der verschiedenen Genera (deren Symbol in äussersten Kreis) zur Hauptverbindung vereinigen.	101. In the adjacent figure, the main result of the compound ratios is compiled. The number indicates how many atoms of X (inner circle) or Θ (outer) unite with one atom of the different genera (their symbol in the outermost circle) to [give] the main compound.
102. Man sieht was sowohl die Verhältniss der X als der Θ Verbindungen von A an regelmässig nach jeder Richtung wachsen, bei Θ unter der Trigonoiden bei Tι unter der Tetragonoiden ihr Maxima erreichen. Die Ordnung des Elements ist dieselbe wie in § 37.	102. One can see that the ratio in both the X and the Θ compounds grows regularly from [point] A in every direction, reaching their maxima at Θ under the trigonoid [and] at Tι under the tetragonoids. The order of the elements is the same as in § 37.
103. Die Ursache, warum allgemein Υ_2 oder X_2 durch Θ ersetz werden kann ist in §.72, §.74 anzugeben.	103. The reason why Υ_2 or X_2 in general can be replaced by Θ is given in §.72, §.74.
104. Affinität, wie gewöhnlich verstanden (?) ist nur ein Scheinwort, Mysticismus. Dagegen erklären Berthollet‘s Gesetze sehr viele chemische Reactionen indem die dieselben auf schon vorher bekannte physikalische Eigenschaften (Flüchtigkeit und Löslichkeit) beziehen. Von diesen ist die Flüchtigkeit in gegenwärtige Schrift auf ihre Grundursache zurückgeführt; damit sind also alle die äusserst zahlreichen dadurch bestimmenden chemischen Reactionen erklärt. In Bezug auf Löslichkeit ist auch einige Klarheit gewonnen, wenn auch bei weitem noch nicht genug.	104. Affinity, as usually understood, is only a pseudoword, a mysticism. In contrast, Berthollet's laws explain many chemical reactions by referring to well-known physical properties (volatility and solubility). Of these, the volatility, in current work, is traced back to its root cause; this explains all the numerous chemical reactions that determine it. Some clarity has also been gained with regard to solubility, if also by far not enough.
105. Die Verbindungswärme, d[as] h[eisst] die durch chemisch Verbindung hervorgebunden Wärme wird wohl in folgende Weise aufzufassen sein. Ein Körper von der Masse *m* entwickelt auf der Erde indem er sich der Oberfläche um *h* nährt eine lebendige Krafte = 2 $g\ m\ h$; um derselben er muss zu entfernen, wäre ein ebenes grosse Aufwand an lebendiger Kraft nöthig.	105. The heat of bonding, that is, the heat which is produced by chemical bonding, may well be interpreted in the following way. By approaching to the surface of the earth by [distance] *h*, a body of mass *m* develops a vis viva = 2 $g\ m\ h$; in order to remove it, a great deal of vital force would be required.

Wärme ist aber lebendige Kraft. Jeder Atom ist ein Mikrokosmischen Himmelskörper, ebenso wie jeder Himmelskoerper ein Kosmischer Atome ist. Daher wird die in Verbindungen stattfindende annäherung der Atome eine der obigen Formel entsprechende Wärmeentwicklung hervorbringen wenn eine Annährung stattfindet, und eine wärmeabgabe ein entgegengesetzten Fälle. Es handelt sich, also um die Bestimmung von *h*; die Mechanik wird diese Bestimmung aus unsern Atomformel ableiten können, sobald die Frage in Bezug auf Aetherhüllen oder Schwingungen genauer erördert ist, d[as] h[eisst] sobald die abstossende Kraft (wenn es ein solche giebt, oder ihr Aequivalenz ein Bewegung) wodurch die Atome auseinander gehalten werden bestimmt ist.	But heat is living force. Every atom is a microcosmic celestial body, just like every celestial body is a cosmic atom. Therefore, the assumption of atoms approaching in compounds will produce a heat generation corresponding to the above formula when a convergence takes place, and a heat release in opposite cases. It is about the determination of h; mechanics will be able to derive this determination from our atomic formula, as soon as the question regarding ether envelopes or vibrations has been more precisely discussed, that means as soon as the repulsive force (if there is any, or its equivalency a movement) by which the atoms are kept apart is determined.
106. Jedenfalls aber sind die bei verschiedenen Verbindungen derselben Elemente fanwendenden Wärmemengen durch Obiges erklärt. In von Farve gefundenen Resultaten geben:	106. In any case, the amounts of heat used in different compounds of the same elements are explained by the above. Results found by Favre give:
$As_2O_3:As_2O_5 = 3:4.64$ statt [instead of] 3:5 $P_2O_3:P_2O_5 = 3:4.64$ statt [instead of] 3:5 $P_2O_3:P_2O = 3:1.05$ statt [instead of] 3:1 $PCl_3:PCl_5 = 1:1.06$ statt [instead of] 3:5	$SO:SO_2:SO_3 = 1:1.95:3.32$ statt [instead of] 1:2:3 $SeO:SeO_2:SeO_3 = ?:2:3.12$ statt [instead of] 1:2:3 $CO:CO_2 = 1:3.27$ statt [instead of] 1:2
Hier ist ganz offenbar, dass die 5 Cl nicht als dicht an P treten können, wie 3 Cl (siehe §.94), daher die geringe Wärmeentwicklung für PCl_5.	Here it is quite clear that the 5 Cl cannot come as close to P as 3 Cl (see §.94), hence the low heat development for PCl_5.
107. Es bedarf kaum eines Beweises dass die stattfindende Condensation in den Verbindungen RH_n für $n > 1$ durch aus unzureichend ist für die Erklärung der Wärmeerscheinungen. Fanden doch Favre [und] Silberman nur eine Erhöhung der Temperatur des H um 13.2 °C wenn es auf das halben Volume zusammengedrückt wurde.	107. It is hardly necessary to prove that the condensation taking place in the RH_n compounds for $n > 1$ is inadequate for the explanation of the heat phenomena. Favre [and] Silberman found an increase in the temperature of H of only 13.2 °C when it was squeezed to half the volume.
[Translator's note: paragraphs 108-120 deal with ternary compounds.]	
Dritter Abschnitt. Physikalische Eigenschaften.	**Third section. Physical Properties.**
[Translator's note: Paragraphs 121-228 omitted]	
Vierter Abschnitt. Morphologische Eigenschaften oder die Krystallformen.	**Fourth section. Morphological Properties or Crystal Forms.**
[Translator's note: Paragraphs 229-399 omitted]	

Schluss	Closing
400. Nachdem wir nun an dem uns einstweilen gesteckten Ziele angelangt sind, und auf das Geleistete zurückblicken gemahnen wir nur zu wohl der vielen Unvollkommenheiten, dir manchen Unvollständigkeiten. Aber diese Arbeit ist nur das Programm der Atomechanik, nur die erste Anzeige dessen, was der Forschung auf diesem neuen Gebiete möglich sein wird. Wenn man berücksichtigt, dass der Raum jede Ausführlichkeit von vorne herein verbot (daher auch seitens der Leser der grösste Aufmerksamkeit nöthig sein wird) so wird man doch wohl zugeben, dass redlich Alles geleistet worden, was unter den obwaltenden Verhältnissen möglich war.	400. Now that we have reached the goals we have sent for the time being, and looking back on what we have achieved, we are reminded only too well of the many imperfections, the many omissions. But this work is just the program of atomechanics, just the first indication of what research will be possible in this new area. If one takes into account that space forbids any elaborateness from the outset (therefore the reader will also need the greatest attention), one will surely admit that everything that was possible under the prevailing conditions was honestly achieved.
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Zur Nachricht.	Note.
Den für Deutschland bestimmten Exemplaren werden das französische Résumé (S. 45-48) im Allgemeinen nicht beigegeben werden.	The copies intended for Germany will in general not include the French résumé (pp. 45-48).

References

1. Hinrichs GD (1867) Programme der Atomechanik oder die Chemie eine Mechanik der Panatome. Privately printed, Iowa City, IA
2. Hinrichs G (1867) A programme of atomechanics, or chemistry as a mechanics of the panatoms. Am J Min 4:66, 82, 98, and 114. This paper was also issued as an offprint, of which very few copies survive
3. Hinrichs G (1869) Natural classification of the elements. Pharmacist (Chicago) 2:10–12
4. Hinrichs G (1870) On the classification and the atomic weights of the so-called chemical elements, with reference to Stas' determinations. In: Proceedings of the American Association for the Advancement of Science: eighteenth meeting, held in Salem, Massachusetts in August, 1869, Joseph Lovering, Cambridge, MA, pp 112–124
5. Hinrichs G (1870) Contributions to molecular science, or atomechanics, Nos. 3, 4. Essex Institute Press, Salem, MA
6. Zapffe CA (1969) Gustavus Hinrichs, precursor of Mendeleev. Isis 60:461–476
7. van Spronsen JW (1969) The periodic system of chemical elements. Elsevier, Amsterdam

8. van Spronsen JW (1969) Gustavus Detlef Hinrichs discovered, one century ago, the periodic system of chemical elements. Janus 56:46–62
9. Kauffman GB (1969) American forerunners of the periodic law. J Chem Educ 46:128–135
10. Giunta CJ (1999) J. A. R. Newlands' Classification of the Elements: Periodicity, But No System. Bull Hist Chem 24:24–31.
11. Scerri ER (2001) A philosophical commentary on Giunta's critique of Newlands' classification of the elements. Bull Hist Chem 26:124–129
12. Wylie CC (1930) Gustavus Detlef Hinrichs. Palimpsest 11:193–201
13. Berg CP (1980) The University of Iowa and biochemistry from their beginnings. The University of Iowa, Iowa City
14. Stolz G (1998) Gustav Dethlef Hinrichs. Ein Naturforscher von Weltruf aus Dithmarschen 1836–1923. Verein für Heimatgeschichte des Kirchspiels Lunden, Lunden, Germany
15. Lang WC (1941) A history of the State University of Iowa: the collegiate department from 1879 to 1900. Thesis, State University of Iowa
16. Keyes C (1924) Contributions to knowledge by Gustavus Detlef Hinrichs, M.D., LL.D. Proc Iowa Acad Sci 31:79–94
17. Gustavus Hinrichs Papers. University of Iowa Archives. RG99.0039
18. Gustavus D. Hinrichs Papers, 1837–1917. Illinois History and Lincoln Collections, University of Illinois at Urbana-Champaign. IHLC MS 712
19. Wolf RA (2020) Brief history of Gustavus Hinrichs, discoverer of the derecho. https://www.spc.noaa.gov/misc/AbtDerechos/hinrichs/hinrichs.htm. Accessed 13 Feb 2020
20. Giacomelli J (2017) Unsettling gilded-age science: vernacular climatology and meteorology in the "Middle Border". Hist Meteorol 8:15–34
21. Palmer WP (2007) Dissent at the University of Iowa: Gustavus Detlef Hinrichs—chemist and polymath. Chemistry: Bulg J Sci Educ 16:534–553
22. Hinrichs G (1866) On the spectra and composition of the elements. Am J Sci 42:350–368
23. Prout W (1815) On the relation between the specific gravities of bodies in their gaseous state and the weights of their atoms. Ann Phil 6:321–330
24. Prout W (1816) Correction of a mistake in the essay on the relation between the specific gravities of bodies in their gaseous state and the weights of their atoms. Ann Phil 7:111–113
25. Thomson T (1816) Some observations on the relations between the specific gravity of gaseous bodies and the weights of their atoms. Ann Phil 7:343–346
26. Farrar WV (1965) Nineteenth-century speculations on the complexity of the chemical elements. Brit J Hist Sci 2:297–323
27. Brock WH (1985) From protyle to proton: William Prout and the nature of matter, 1785–1985. Adam Hilger Ltd., Bristol and Boston
28. Stas JS (1860) Recherches sur les rapports réciproques des poids atomiques. Bull Acad R Belg 10:108–336
29. Stas JS (1865) Nouvelles recherches sur les lois des proportions chimiques, sur les poids atomiques et leurs rapports mutuels. Mem Acad R Sci Lett Beaux-Arts Belg 35:3–311
30. Cannizzaro S (1858) Lezioni sulla teoria atomica fatte nella R. Università di Genova. La Liguria Medica, G Sci Med Nat 3:113–142
31. Cannizzaro S (1858) Sunto di un corso di filosofia chimica fatto nella R. Università di Genova dal Prof. S. Cannizzaro. Nuovo Cimento 7:321–366
32. Will H (1863) [published in 1864] Jahresber Fortschr Chem Verw Theile Anderer Wiss, p xxiv
33. Gladstone JH (1853) On the relations between the atomic weights of analogous elements. Phil Mag 5:313–320
34. Cooke JP (1855) The numerical relation between the atomic weights, with some thoughts on the classification of the chemical elements. Am J Sci 17:387–407. Cooke's paper was also printed in (1855) Mem Am Acad Arts Sci 5:235–257 and 412

35. Dumas JBA (1851) Observations on atomic volumes and atomic weights, with considerations of the probability that certain bodies now considered elementary may be decomposed. The Athenaeum 750; L'Inst, J Univ Sci Soc Sav Fr. L'Etrang 19:303–304
36. Dumas JBA (1857–58) Mémoire sur les équivalents des corps simples. C R Séances Acad Sci 45:709–731; 46:951–953; 47:1026–1034
37. Lea MC (1860) On numerical relations existing between the equivalent numbers of elementary bodies. Am J Sci Arts 29:98–111
38. Béguyer de Chancourtois A-E (1863) Vis tellurique. Classement naturel des corps simples ou radicaux obtenu au moyen d'un système de classification hélicoïdal et numérique. Mallet-Bachelier, Paris
39. Odling W (1864) On the proportional numbers of the elements. Quart J Sci 1:642–648
40. Newlands JAR (1864) Chem News 10:59–60 and 94–95; (1865) Chem News 12:83; (1866) Chem News 13:113
41. Meyer L (1864) Die modernen Theorien der Chemie und ihre Bedeutung für die chemische Statik. Maruschke & Berendt, Breslau
42. Darwin Correspondence Project. 2020. Letter of G. D. Hinrichs to Charles Darwin, 31 Aug 1868. "Letter no. 6337," https://www.darwinproject.ac.uk/letter/DCP-LETT-6337.xml. Accessed 25 Feb 2020
43. Rose H (1857) Ueber die Atomgewichte der einfachen Körper. Ann Phys Chem 176:270–291
44. Krönig A (1866) Neues Verfahren zur Ableitung der Formel einer Verbindung aus den Gewichtmengen der Bestandtheile. Springer, Berlin
45. Daubeny C (1831) An introduction to the atomic theory. John Murray, Oxford
46. Marignac C (1843) Analyses diverses destinées à la vérification de quelques équivalents chimiques. Biblioth Univ Genève 26:350–373
47. Maumené E (1846) Sur les équivalents chimiques du chlore, de l'argent et du potassium. Ann Chim Phys 18:41–79
48. Marignac C (1865) Remarques sur le mémoire de M. Stas, intitulé "Nouvelles recherches sur les lois des proportions chimiques, &c". Arch Sci Phys Nat 24:371–376
49. Hinrichs GD (1874) The principles of chemistry and molecular mechanics. Day, Egbert, & Fidlar, Davenport, IA; B. Westermann & Co., New York, NY, p 166
50. Dana JD (1867) On a connection between crystalline form and chemical constitution, with some inferences therefrom. Am J Sci 44:89–95 and 252–263
51. Girolami GS (2009) Origin of the terms pnictogen and pnictide. J Chem Educ 86:1200–1201
52. Claus CE (1845) Fortsetzung der Untersuchung des Platinrückstandes, nebst vorläufiger Ankündigung eines neuen Metalles. Bull Cl phys-math Acad imp sci St-Pétersbg 3:col. 353–371
53. Berzelius JJ (1828) Försök öfver de Metaller som åtfölja Platinan, samt öfver sättet att analysera Platinans nativa legeringar eller Malmer. K Sven Vetenskapsakad Handl 25–116
54. Venable FP (1896) The development of the periodic law. Chemical Publishing Co., Easton, PA
55. Watts H (1863–1868) A dictionary of chemistry and the allied branches of other sciences. Longmans, Green, and Co, London, vol 1, p 907 and vol 3, p 308
56. Hinrichs GD (1894) The elements of atom-mechanics. B. Westermann & Co, St. Louis, MO
57. Mauskopf SH (1969) The atomic structural theories of Ampère and Gaudin: molecular speculation and Avogadro's hypothesis. Isis 60:61–74
58. Cole TM (1975) Early atomic speculations of Marc Antoine Gaudin: Avogadro's hypothesis and the periodic system. Isis 66:334–360
59. Hinrichs G (1868) Synopsis of new memoirs on atomechanics. Privately printed, Iowa City, IA
60. Hinrichs GD (1871) The elements of chemistry and mineralogy, demonstrated by the student's own experiments and observations. Griggs, Watson, and Day, Davenport, IA, p 58
61. Gmelin L (1843) Handbuch der Chemie, K. Winter, Heidelberg, vol I, p. 457

62. Mendeleev DI (1872) Osnovy Khimii, 2nd ed., Tovarishchestva ‘Obshchestvennaia Pol’za’ for the author, St. Petersburg, vol 2, frontispiece
63. Walker J (1891) On the periodic tabulation of the elements. Chem News 63:251–253
64. Girolami GS, Mainz VV (2019) Mendeleev, Meyer, and atomic volumes: an introduction to an English translation of Mendeleev’s 1869 article. Bull Hist Chem 44:100–115
65. Kipnis N (2014) Thermodynamics and mechanical equivalent of heat. Sci Educ 23:2007–2044