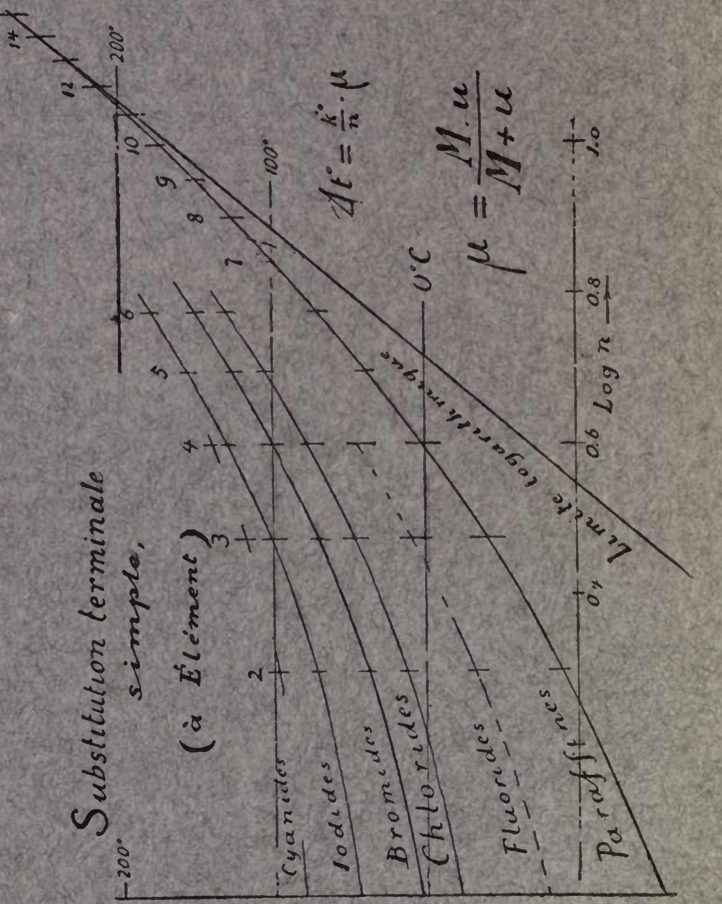
Gustavus Pitley

HINRICHS: The Proximate Constituents OF THE Chemical Elements.

FOR PLATE 5.



By mistake, the cut for *complex* instead of *simple* Terminal Substitution, was inserted on Plate 5.

The very similar figure here printed is the one actually referred to in the text.

To Prof. Eugene Hilgard
with the compliments
of his friend
the author.

THE
PROXIMATE CONSTITUENTS
OF THE
Chemical Elements

THE

PROXIMATE CONSTITUENTS

OF THE

Chemical Elements

MECHANICALLY DETERMINED FROM THEIR
PHYSICAL AND CHEMICAL PROPERTIES

BY

GUSTAVUS DETLEF HINRICHS, M. D., LL.D.,
Honorary and Corresponding Member of Scientific Societies in
Austria, England, France, Germany and the United States;
Professor of Chemistry in the Medical Department,
St. Louis University.

WITH 32 PLATES.

ST. LOUIS, MO., U. S.

CARL GUSTAV HINRICHS, PUBLISHER.

New York and Leipzig, LEMCKE AND BUECHNER.
London, H. GREVEL & CO. Paris, H. LE SOUDIER.

1904.

Press of Nixon-Jones,
215 Pine Street, St. Louis.

TO

PROFESSOR, DOCTOR

CLEMENS ALEXANDER WINKLER,

Geheimer Rat,
Ehrenmitglied des Professoren Kollegiums
der Königlich Sächsischen
BERGAKADEMIE ZU FREIBERG,

HONOR-PRESIDENT
of the
FIFTH INTERNATIONAL CONGRESS
OF APPLIED CHEMISTRY,

THIS VOLUME

IS DEDICATED BY

THE AUTHOR.

PREFACE.

When a boy, I often wondered at the meaning of the following inscription* on a large stone in the high gable of one of the grand old houses in my native town:

EL HOMBRE CUERDO HA DE PEN
SAR QUE MIENTRAS VARIERA EN
ESTA VIDA LA FELICIDAD TIENE
POR EMPRESTADA Y LA ADVER
SIDAD POR SU NATURAL
PATRIMONIO
1649.

When a young man, I read in our modern histories of science of the manifold persecutions which, in darker ages, were the reward of men, who had dared to push beyond the beaten tracks of the schools and authorities to greater heights, and thus had cleared away errors and shown Nature in a brighter light; and I rejoiced that the powers of darkness and superstition happily had been dispelled before my day by a more enlightened civilization to which all deeper knowledge would be welcome.

After half a century of incessant labor in a new field of research full of intrinsic difficulties, I have found the boasted modern civilization only more refined and varied in its methods of persecution and of torture. Some fine instances may be read in my *Darkest America;* see also foot note, p. xi of this book.

Therefore much time and labor has been withdrawn from the loved work of research, and I have not yet been permitted to complete my final exposition of the mechanics of the three states of aggregation and the structure of the crystals.

I have temporarily left this main work in order to present by the inductive method one of its broadest results in this popular

---

* Evidently the experience of some persecuted Spaniard who had sought a place of refuge among the Ditmarsians: —

"The wise man must remember in this changeful life: happiness is "but a loan, and adversity his natural heritage."

treatise on the proximate constitution of the chemical elements, at the time of the International Congress of Arts and Science, to which Ostwald, Van't Hoff and others have been called from across the sea, to instruct us in the Methodology of Science and on the Constitution of Matter.

If mathematical deduction and the concordant results of physical and chemical determinations are to be relied on, the published teachings of some of these prominent scientists are decidedly in error and positively antiquated on points of fundamental importance, though these teachings continue to be accepted in the schools because the authority and power of the official station of these men represses just criticism, as *Ostwald* himself has delighted to explain in reference to a preceding generation.

It remains, however, to be seen, whether the rising generation will ratify the punishment for such criticism of human authority by the suppression of my name while quoting and using my results admitted to be "admirable;" possibly it may happen, that the power of human authority will fail against truth, even in Science.

That this deplorable and reactionary punishment for the holding scientific truth above men however high in public station, is not and has not been deemed proper by all prominent modern men of science, I am happy to demonstrate by the portraits and handwritings of some of the eminent scientists, who have kindly encouraged and assisted me in my life work.

GUSTAVUS DETLEF HINRICHS.

SAINT LOUIS, September 2, 1904.

Publications on Atom-Mechanics.

By GUSTAVUS D. HINRICHS, 1864-1904.

A list of my books and publications on other branches has not been issued since 1885. They treat of Mathematics, Astronomy, Technical Chemistry, General Laboratory Teaching, and are relatively extended on Meteorology, including Meteorites.

I. **Books***—Entirely or largely devoted to this subject.

Programme der Atom-Mechanik, die Chemie eine Mechanik der Pan-Atome.—44 pp. 4 vo., Iowa City, 1867. French Resume of same, 4 pp. 4 vo., November, 1867. English Resume, 4 pp. 4 vo.; August, 1867.

The Principles of Pure **Crystallography.**—Pp. IV, 44, in 8 vo.; Davenport and Leipzig, 1871. See especially, Chapter VI.

The Method of Quantitative **Induction** in Physical Science.—Davenport and Leipzig, 1872. See especially the last section, p. 36, giving the Mechanics of the three States of Aggregation.

The **Principles** of Chemistry and Molecular Mechanics.—200 pp., 8 vo., with two plates. Cloth. Davenport and New York, 1874. Especially pp. 63-66; 110-137; 151-152; 165-182.

Beitrage zur Dynamik des Chemischen Molekuels. Leipzig, Gustav Fock, 1892: I.—The Molecule as a System of Material Points. II.—The Energy of the Molecule. III.—Graphical Structural Formula. IV.—The Moments of Inertia of the Molecules. V.—The Motions of the Molecules. VI.—The Boiling Points of Isomeric Bodies Determined by the Moment of Inertia of the Molecules. These papers were first sent to the Deutsche Chemische Gesellschaft, I, II, April, 1872; III-VI, April, 1873, of which I was a member.**

The **True Atomic Weights** of the Chemical Elements, and the

---

* The catch-word specially accentuated will be used for brief references in quotations.

** The most remarkable history of the original paper is given in the edition of 1892.

Unity of Matter.—Pp. XVI, 256, 8 vo., 7 plates, many illustrations; fine paper, cloth binding. St. Louis and New York, 1894.

Introduction to **General Chemistry.**—A graded course of 100 lectures, with an Atlas of 80 plates, representing Chemists, Institutions, Prime Materials, Crystals, Diagrams and Apparatus; 400 pages, 8 vo.; bound in cloth. St. Louis and New York, 1897. Especially lectures 91 to 100 (pp. 350-382).

The **Absolute Atomic Weights** of the Chemical Elements * * * and the Unity of Matter.—With portrait of Berzelius anl three plates. St. Louis, 1901; XVI, 304 pp. $8.00.

Introduction to **Crystallographic Chemistry**—36 pp. text and 40 pp. plates. 8 vo. Issued as introduction to first course in **Microchemical Analysis** by Carl Gustav Hinrichs. St. Louis, New York and Leipzig, 1904. 156 pp., 8 vo., of which 64 pp. plates.

The Proximate Constituents of the Chemical Elements mechanically determined from their Physical and Chemical Properties. St. Louis, New York and Leipzig, 1904. 8 vo. 32 pp. plates, 112 pp. text.

II. Academy of Sciences of Vienna.—Stizungsberichte. Presented by Wilhelm Haidinger. On the (Crystal) **Structure of Quartz.**—I Abthl., vol. 61, pp. 83-88, 1870. On the Statics of **Crystal-Symmetry.**—II Abthl., vol. 62, pp. 345-361, 1870. Chemico-Physical remarks on the Reality of Rhombo-Tesseral Forms.—Anzeiger, 1869, No. 1.

III. Academy of Sciences of Paris.—Comptes Rendus. Presented by Marcelin Berthelot. For reference*, these papers will be specified by number as "**Notes.**"

FIRST SERIES.—General Mechanics of the Three States of Aggregation.

I.—On the Molecular Rotation of Gases. June 2, 1873.—T. 76, p. 1357.

II.—On the Boiling Points and the Molecular Volumes of the Isomeric Chlorides of the Ethyl Series. June 9, 1873.—T. 76, p 1408.

III.—On the Calculation of the Moments of Inertia of Molecules. June 30, 1873.—T. 76, p. 1592.

IV.—On the Atomic Structure of the Molecules of Benzine and Terebene. January 4, 1875.—T. 80, p. 47.

V.—Calculation of the Maximal Moments of Inertia of the Molecules of the Chlorine Derivatives of Toluene. March 1, 1875.—T. 80, p. 565.

VI.—On the Determination of the Boiling Points of the Chlorine Derivatives of Toluene. March 22, 1875.—T. 80, p. 766.

---

* The date of the session and volume (T, tome, and page are given.

SECOND SERIES.*—The General Relations Between Boiling Point, Pressure and Atomic Weight and Form of Compounds.

VII.—Statement of the General Law determining the Fusing and Boiling Points of any Compound under any Pressure, as Simple Function of the Chemical Constitution of the same. May 4, 1891.—T. 112, p. 998.

---

* As resident member of a certain Academy of Science I read at its meetings, in the Fall of 1890 and Winter of 1891, several papers, covering the ground of this **second series,** which papers are mentioned by title in the published proceedings of that Academy.

No steps to their publication being taken, I stopped my scientific contributions to this Academy and, in order to protect my scientific work, sent on April 17, 1891 a note (No. VII of this list) to **M. Berthelot** of the Academy of Science of Paris.

Already on May 1, 1891, I received the following cablegram from Paris, of same date which also is the date on which **Berthelot** received my letter and manuscript:

> "Your note will be printed in the Comptes Rendus before "the 15th of May. **Berthelot."**

My note was presented to the French Academy by **M. Berthelot** at its first meeting after the receipt of my paper, namely on May 4th, 1891.

The number of the Comptes Rendus of that meeting, containing my paper, was issued according to rule on the day of the next meeting, which was on May 11. Thus the promise given by the cablegram was fulfilled to the letter.

This simple statement of facts and dates I will, at this time, supplement with only the further statement, that some defect in my English was intimated to have been detected by some eminent scholar on the committee on publication of our local Academy of Sciences.

I therefore sent a paper of mine to the London **"Nature".** In the number of this first class English journal of June 25, 1891 I found that paper printed exactly as written by me; I have kept the duplicate carbon thereof.

Since now my **Science** was accepted promptly and published immediately by the Academy of Science of Paris, and since my **English** was good enough for one of the best of the scientific journals of London, I tried to forget the treatment received from the few fellow-members of our local Academy of Science, who mismanaged its affairs.

With some difficulty I re-obtained possession of my original papers, which I have carefully preserved in my safe on account of the few, but no doubt highly inportant and most valuable improvements in science and languague marked by the eminent censors, but which improvements I have not yet had occasion to publish for the benefit of the scientific world.

Regretting that the traits so prominent in some of our political meetings are not strangers in professedly scientific societies, I have tried to get along in my scientific work without again seeking any of the advantages for which that Academy of Sciences was founded.

Possibly such management may largely account for the rather insignificant work our Academies of Sciences accomplish in the advancement of science.

VIII.—Calculation of the Fusing and Boiling Points of Normal Paraffins. May 19, 1891.—T. 112, p. 1127.

IX.—Calculation of the Boiling Point of Any Liquid Under Any Pressure. June 22, 1891.—T. 112, p. 1436.

X.—Calculation of the Molecular Volume. July 6, 1891.—T. 113, p. 36.

XI.—Mechanical Determination of the Linkage of the Carbon Atoms in Organic Compounds. August 17, 1891.—T. 113, p. 313.

XII.—Calculation of the Specific Heat. October 12, 1891.—T. 113, p. 468.

XIII.—Calculation of the Magnetic Rotation of the Plane of Polarization of Light. October 19, 1891.—T. 113, p. 500.

XIV.—Mechanical Determination of the Position of the Hydrogen Atoms in Organic Compounds. November 23, 1891.—T. 113, p. 743.

XV.—Calculation of the Boiling Point of the Isomeric Ethers of the Fatty Acids. December 7, 1891.—T. 113, p. 798.

THIRD SERIES.—The General Mechanical Effects of Chemical Substitution.

XVI.—Calculation of the Boiling Point of Compounds Derived From the Paraffins by Terminal Substitution. March 14, 1892.—T. 114, p. 597.

XVII.—Determination of the Boiling Surface of the Normal Paraffins. May 2, 1892.—T. 114, p. 1015.

XVIII.—Establishment of the Formulae for the Calculation of the Maximal Moments of Inertia. May 9, 1892.—T. 114, p. 1064.

XIX.—Mechanical Determination of the Boiling Points of Compounds of Simple Terminal Substitution. May 16, 1892.—T. 114, p. 1113.

XX.—Mechanical Determination of the Boiling Points of Compounds of Complex Terminal Substitution. May 30, 1892.—T. 114, p. 1272.

XXI.—Mechanical Determination of the Boiling Points of Alcohols and Acids. June 7, 1892.—T. 114, p. 1367.

XXII.—On the Mechanical Contrast Between the Radical Cyanogene and the Chloroid Elements. July 18, 1892.—T. 115, p. 177.

XXIII.—The Specific Heat of the Atoms and Their Mechanical Constitution. July 25, 1892.—T. 115, p. 239.

XXIV.—On the General Form of the Boiling Point Curves of the Compounds Resulting from Central Substitution. August 8, 1892.—T. 115, p. 314.

FOURTH SERIES.—Determination of the True Atomic Weight of the Elements.

XXV.—Critical Reduction of Fundamental Determinations of Stas on Potassium Chlorate. December 12, 1892.—T. 115, p. 1074.

XXVI.—On the Determination of the Atomic Weight of Lead by Stas. February 27, 1893.—T. 116, p. 431.

XXVII.—General Method for the Calculation of the Atomic Weights From the Results of Chemical Analysis. March 27, 1893.—T. 116, p. 695.

XXVIII.—Determination of the Atomic Weight by the Limit Method. April 10, 1893.—T. 116, p. 753.

XXIX.—Determination of the True Atomic Weight of Hydrogen. November 13, 1893.—T. 117, p. 663.

XXX.—Outline of the System of Atomic Weights of Precision, Based Upon the Diamond as Standard of Matter. December 26, 1893.—T. 117, p. 1075.

XXXI.—On the Atomic Weights of Precision, Determined by Using Silver as Secondary Standard of Matter. March 5, 1894.—T. 118, p. 528.

XXXII.—On the Atomic Weight of Boron. June 18, 1900.—T. 130, p. 1712.

XXXIII.—On the Atomic Weight of Ten Elements Determined From Recent Experiments. July 2, 1900.—T. 131, p. 34.

FIFTH SERIES.—Diverse Topics.

XXXIV.—On the Composition of the Air in the Vertical, and on the Constitution of the Higher Strata of the Earth's Atmosphere. August 20, 1900.—T. 131, p. 442.

XXXV.—Preliminary Notice of an Inverse Genus of Common Meteoric Stones. Presented by A. Daubree. June 18, 1894.—T. 188, p. 1418.

XXXVI.—The Oscillation of Mid-November in America. Presented by Chas. St. Claire-Deville. February 28, 1876.—T. 82, p. 520.

IV. Contributions to Molecular Science—Being Reprints from the Proceedings of the American Association for the Advancement of Science.

Chicago Meeting, 1868

1. The Statics of the Four Types of Modern Chemistry, With Especial Regard to the Water Type. Vol. 17, pp. 207-223.
2. A New and General Law Determining the Atomic Volume and Boiling Point of a Great Number of Carbon Compounds. Vol. 17, pp. 223-238. 1868.
   On the Calculation of the Crystalline Form of the Anhydrous Carbonates, Nitrates, Perchlorates, Permanganates, and Other Salts of Like Composition. Vol. 17, p. 345. 1868. Read by title.

Salem Meeting, 1869:

3. On Molecular Perturbations. Vol. 18, pp. 100-112. 1869.
4. On the Classification and the Atomic Weights of the So-Called

Chemical Elements, With Reference to Stas' Determinations. Vol. 18, pp. 112-124. 1869.

On Atomic Volume and Atomic Distances of the Crystallized A B^3 C. Vol. 18, p. 275. 1869. Read by title.

The following papers were read, but not printed, the Association now publishing its proceedings late and with abstracts only:

Dubuque Meeting, 1872:

On the Dynamical Conditions of the Three States of Aggregation. Vol. 21, p. 258. 1872.

Washington Meeting, 1891:

Statement of the General Law Determining the Fusing and Boiling Point of Any Compound, Under Any Pressure as Simple Function of the Chemical Constitution of the Same. Vol. 40, p. 144.

The Calculation of the Boiling Point of a Liquid Under Any Pressure. Vol. 40, p. 141.

Determination of the Discontinuity of the Fusing Points of Paraffins by Means of Analytical Mechanics. Vol. 40, p. 141.

The Calculation of the Boiling Point of Any Paraffin Under Any Pressure. Vol. 40, p. 190.

The Calculation of the Boiling Points of Isomerics From Their Moments of Inertia. Vol. 40, p. 190.

Determination of the True Position of Carbon Atoms in Organic Compounds by Means of Analytical Mechanics. Vol. 40, p. 190.

Rochester Meeting, 1892:

On the Mechanics of the Three States of Aggregation. Vol. 41, p. 90.

On the Mechanical Determination of the Stereographic Constitution of Organic Compounds. Vol. 41, p. 114.

Madison Meeting, 1893:

On the Systematic Errors Affecting All the Atomic Weights of Stas'. Vol. 42, p. 107.

V. Publications in Divers Periodicals.

American Pharmaceutical Association.—Forty-first Annual Meeting, Chicago, August 14-20, 1893:

On the Atomic Weights of the Chemical Elements. Minutes of Proceedings, Philadelphia, 1893; pp. 104-106.

American Journal of Science:

On the Distribution of the Dark Lines in the Spectra of the Elements. Vol. 38, pp. 31-40. 1864.

On the Spectra and Composition of the Chemical Elements. Vol. 42, pp. 350-360. 1866.

The Crystalline Form of the Anhydrous Carbonates.*

American Journal of Mining. New York, 1867:

Synopsis of the Programme of Atom-Mechanics. June, 1867.

Atom-Mechanics Proved by Tyndall's Experiments. May 2, 1868.

Scientific American. New York:

How a Snowflake Is Built. April 18, 1868. Illustrated.

The Pharmacist. Chicago:

Natural Classification of the Elements. July, 1869.

Comptes Rendus. Academy of Science of Paris:

Note on the Crystal-Form of Sulphates. T. 68, p. 344. 1869.

Zeitschrift fur Physikalische Chemie. Leipzig:

On the Tension of Saturated Vapor of Water. Bd. VIII, p. 680. 1891. Also in Vol. VIII (1891), the following of the Second Series of my Contributions to Atom-Mechanics: VII, p. 229; VIII, p. 232; IX, p. 340; XI, p. 677. Also in Vol. IX (1892): Contribution X, p. 81.

Kruess Zeitschrift fuer Anorganische Chemie. Hamburg:

The Determination of the True Atomic Weight of Copper. Bd. V, p. 293. 1893.

Chemical News. London:

The Specific Heat of the Atoms and Their Mechanical Constitution. Vol. 66, p. 116. Sept. 2, 1892.

Determination of the True Atomic Weight of Copper. Vol. 68, p. 171. Oct. 6, 1893.

Nature. London:

Statement of the General Law Determining the Fusing and Boiling Points of Any Compound Under Any Pressure, as Simple Function of the Chemical Constitution of the Same. June 25, 1891.

---

* The general results of this paper were published in the July and September numbers of 1867, after having been in the hands of the editor during the months of March, April and May, 1867. Naturally, I have not given the editor a chance for further exhibitions of what he calls "independent action in independent minds."

EMINENT SCIENTISTS

WHO HAVE
ENCOURAGED AND ASSISTED THE AUTHOR
IN HIS WORK ON

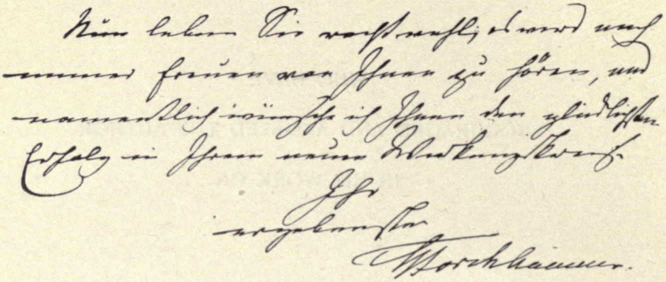
ATOM-MECHANICS

AND THE

COMPOSITION OF THE CHEMICAL
ELEMENTS

FROM

1855 to 1904.



Nun leben Sie wohl recht, ich hoffe auch
immer ferner von Ihnen zu hören, und
namentlich wünsche ich Ihnen den glücklichsten
Erfolg in Ihrem neuen Wirkungskreise.
Ihr
ergebenster
GForchhammer.

JOHANN GEORG FORCHHAMMER.

Born July 26, 1794, at Husum, Slesvig; died December 14, 1865, at Copenhagen, Denmark. Professor of Mineralogy at the University since 1835 and Professor of Chemistry at the Polytechnic School, both of Copenhagen; Director of the latter since 1851. For many years the most noted chemist and most influential man of science in Denmark.

I have been under great obligations to Forchhammer from my entrance in 1853 (see Absol. At. Wghts., p. 84–5, also True At. Wghts., p. 51–55). Dedicated my first book (Hamburg, 1856) to him. Received two stipends, one of 100, a second of 200 Dalers from the Holstein Government, mainly through his influence.

The above autograph are the closing words of his last letter to me, written (October 11, 1865) only two months before his death. His handwriting (German) always was like an engraving and hardly requires a translation; he "especially wishes me the happiest success in my new sphere of action" at the State University of Iowa.

FORCHHAMMER.

In treuer Verehrung und Dank-
barkeit Ihr ergebenster W Haidinger

WILHELM HAIDINGER.

Born February 5, 1795, at Vienna, Austria, where he died March 19, 1871. Haidinger was one of the most noted Mineralogists and Crystallographers of his time, one of the founders of the Academy of Sciences of Vienna (1847) and founder of the Geologische Reichsanstalt of Austria, also greatly developed the collection of Meteorites at Vienna.

The first letter from his hand is dated December 10, 1856; the last bears date of December 2, 1870, written only three months before his death. My biographical sketch of his life, with a fine lithograph of his last photograph, was published in 1871 (16 pp. 8vo.).

I am not only indebted to him for many encouraging letters, but also for the presentation of two of my crystallographic papers to the Academy, published in the Sitzungsberichte for 1870. His Mineralogie (1845) is especially profound in its crystallographic part, on which I have drawn in my recent Crystallographic Chemistry (p. 10–11).

HAIDINGER.

Dans cet ouvrage et dans
plusieurs points j'ai été encouragé
par vos importantes decouvertes et
j'en ai largement profité!

Votre très devoué servitr
P. A. Secchi.

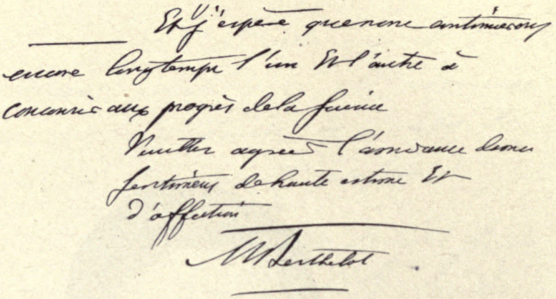
FATHER ANGELO SECCHI, S. J.

Born June 29, 1818, at Reggio, Emilia, Northern Italy; died February 26, 1878, at Rome. Part of his high mathematical training he received at the University of his order at Georgetown, near Washington, D. C., where he also spent the "years of exile," 1848-9. He built in 1852 and directed till his death the Astronomical Observatory of the Collegio Romano.

He is famous both as Meteorologist (his Meteorograph was shown at the Paris Exposition of 1867 and won the prize of 100,000 francs) and as Astronomer, being the first to classify the stars according to their spectra or chemical constitution. His most noted works are "The Unity of the Physical Forces," 1864, and "The Sun," the second edition forming two magnificently illustrated volumes (1875 and 1877). Quotations from my works in the *first*, p. 495, in the *second*, Vol. II, pp. 377-381.

His letter quoted from above is dated "Rome, April 19, 1877," or less than a year before his death. The quotation reads in English: "In this work and in several "places, I have been encouraged by your important discoveries, and I have been "greatly profited thereby."

P. SECCHI.



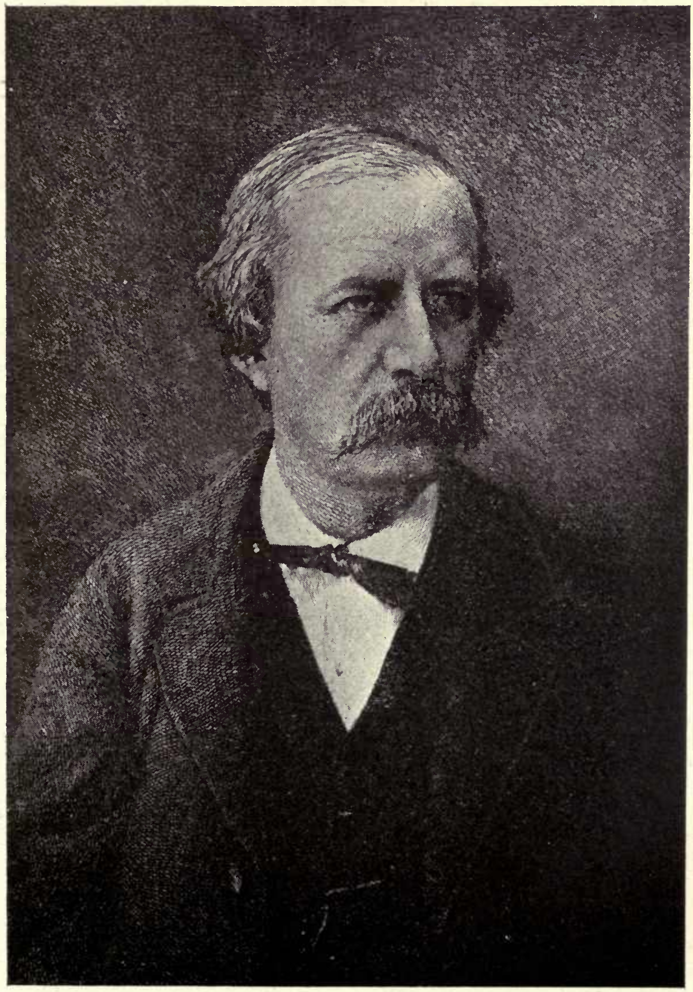
Et j'espère que nous continuerons
encore longtemps l'un et l'autre à
concourir aux progrès de la science
Veuillez agréer l'assurance de mes
sentiments de haute estime et
d'affection
M Berthelot

MARCELIN PIERRE EUGENE BERTHELOT.

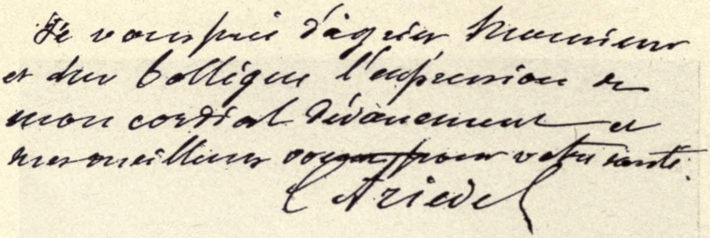
Born October 25, 1827, at Paris. For half a century a most successful investigator and writer, especially on chemical synthesis, thermochemistry and the history of chemistry. Since 1864 Professor at the College de France, and since 1889 one of the two perpetual Secretaries of the Academy of Sciences of Paris.

Without any introduction but my own letter he presented, in June, 1873, my first *Note* on *the Rotation of the Molecules.* He has since presented about 35 additional Notes from me which have appeared in the Comptes Rendus and form a volume of 140 pages in quarto. In July, 1873, I had the honor, as his guest, to explain my mathematical work to his friend *Bertrand*, the mathematician. The two future perpetual Secretaries of the Academy of Sciences of Paris were the most interested and influential students ever addressed by me. My "True Atomic Weights" was dedicated to Berthelot. I most sincerely thank him and the French scientists for the courtesies extended to me and my work.

The above autograph forms the closing words of his letter of May 4, 1897, and reads in English: * * * and I hope that we may continue for still a long time both the one and the other to concur in the progress of science. Please accept the assurance of my sentiments of high esteem and affection.



BERTHELOT.



Je vous prie d'agréer Monsieur
et cher Collègue l'expression de
mon cordial dévouement et
mes meilleurs vœux pour votre santé.
C Friedel

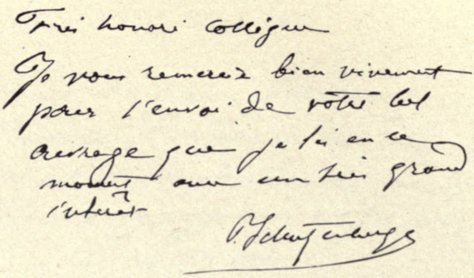
CHARLES FRIEDEL.

Born March 12, 1832, at Strassburg, Alsace (then France); died April 20, 1899, at Montauban, France. Was Professor of Mineralogy at the School of Mines, and of Organic Chemistry at the University of Paris.

The province of Alsace was torn by France from the old German Empire during the dreadful thirty years' war; it has given to France a remarkably large number of famous men who, while all patriotic Frenchmen, in their life work revealed their Teutonic traits as plainly as in their name. "The pleiade of chemists of Alsace," composed of Gerhardt, Wurtz, Friedel and Schützenberger, is a striking example. Gerhardt's revolutionary work aided me at the beginning of my research, the others I met at Paris, in 1873. The last two have since greatly helped and befriended me. Friedel honored me by accepting the dedication of my General Chemistry in 1897.

The autograph presented is the close of his letter of September 23, 1896: "I beg "you to accept, Monsieur and dear Colleague, the expression of my cordial devotion "and my best wishes for your health."

FRIEDEL.



Très honoré Collègue
Je vous remercie bien vivement
pour l'envoi de votre bel
ouvrage que je lis en ce
moment avec un très grand
intérêt
P. Schützenberger

PAUL SCHÜTZENBERGER.

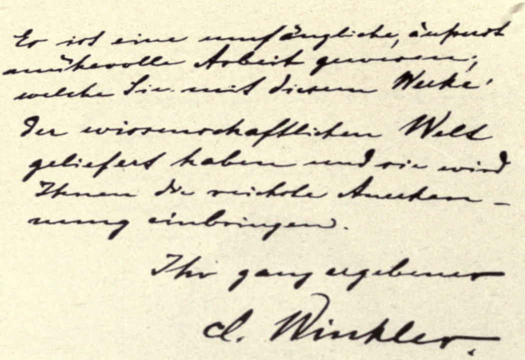
Born December 23, 1829, at Strassburg, Alsace (then France), died June 26, 1897, at Mezy, France. Professor of Chemistry at the College de France since 1876.

This renowned chemist of "the Alsace Pleiade" carried out most important researches on the metals of the rare earths in the hope of finding some proof of their complex nature.

In a public lecture at the Sorbonne (the University of Paris) and under the presidence of Friedel, Professor Schützenberger gave to an audience of French Chemists a full exposition of my work as published in my "True Atomic Weights." This lecture forms the opening article of the new chemical journal of Friedel, "the Actualites Chimiques," begun 1896. Also in his *Revue* this work of mine is placed at the head. In his posthumous "Chimie generale," Paris, 1898, he again presents the same (pp. 143–152).

The autograph of November 10, 1894, reads: "Highly honored Colleague. I "thank you very much for your fine work which you have sent me and which I am "now reading with the greatest interest."

SCHÜTZENBERGER.



Es ist eine umfängliche, äußerst
mühevolle Arbeit gewesen;
welche Sie mit diesem Werke
der wissenschaftlichen Welt
geliefert haben und sie wird
Ihnen die reichste Anerkennung
einbringen.

Ihr ganz ergebener

Cl. Winkler.

CLEMENS ALEXANDER WINKLER.

Born December 26, 1838, at Freiberg, Saxony, Germany. Since 1875 Professor of Chemistry in the Bergakademie at Freiberg, the oldest technical High School in the world. Some of the most noted pioneers in special branches of modern sciences were professors of this famous school.

The perfection of the analytical work of Winkler astonished me till I found the name of his father, Kurt Winkler, in the list of special students of Berzelius. The Academy of Sciences of Stockholm has published some of Winkler's investigations.

Technical gas analysis, the manufacture of sulphuric acid by the contact method, and the discovery of the rare element Germanium, have long ago made Winkler known throughout the chemical world.

The above autograph forms the conclusion of his letter of October 6, 1901, and reads in English: "It has been an extended, extremely painstaking labor which you "in this book have presented to the scientific world, and it will yield you the richest "recognition."

WINKLER.

CURRICULUM VITÆ.

GUSTAVUS DETLEF HINRICHS was born December 2, 1836, at Lunden, in North-Ditmarsia, in the duchy of Holstein, (then) Denmark, German Confederation; now province of Schleswig-Holstein, Prussia, Germany.

Ditmarsia was for many centuries an independent republic; its history is an account of heroic resistance to more powerful neighbors. The combined forces of Holstein, Schleswig and Denmark finally overcame the republic in 1559. Lunden was the chief town of the Northern Half of the Republic; it still contains buildings and monuments of that time.

Father was surveyor and engineer; several of his ancestors were prominent in the government of the republic as far back as 1434. Our family belonged to the Vogdemannen, originally Vodiems, coming from Frisia about 1200 on account of great storm floods.

Mother's family was Danish; my first great bereavement was the death of my grandmother, who gave me my first instruction in Danish stories.

For study I had few books, but made the most of them — and copied from such I could get for temporary use. I have still quite a notebook full of astronomical excerpts written when I was ten years old. Also used, at that time, a MS. "Steuermannskunde" showing how the ship's place at sea is determined.

The general revolution of 1848 made boys old; in 1850 I ran away and was one day at the fire line. Our German brothers had urged us on in 1848. In 1849 Prussia dropped our cause, and in 1852 the German Powers disarmed us and turned us over again to Denmark. This abandonment made a lasting impression on me, so that I agreed with family and assisting friends and went North to Copenhagen to study, 1853. The mental atmosphere at the school was excellent. Berzelius and Oersted had departed only five and two years before.

During three years I followed the regular course of study, for five years thereafter I studied what I seemed to require for my scientific life work. To be qualified to teach in higher scientific schools I passed the examinations early in 1860, mark "excellent."

By this time the old national antagonism broke out anew. Many friends in high position in Denmark, nearest relatives in the Holstein. I had to go into a foreign land once more, and arrived in America on the eve of the battle of Bull's Run, which opened our Civil War of four years' duration.

Became teacher in a district school; then in a city high school, next in the preparatory school of a State University. In another year I was elected Professor in that institution which I served for a quarter of a century. In 1889 I was called to the city of St. Louis.

I. THE CHEMICAL ELEMENTS.

GRAPHIC REPRESENTATION OF THEIR CHARACTERISTIC PROPERTIES, AND THEIR DIVISION INTO FAMILIES OR GENERA.

The world of matter presents to us a most astounding variety of substances; they differ in every conceivable way. When by our senses unaided we suppose we have found two substances apparently identical, we very often find great differences in properties as soon as we call to the assistance of our senses some of those manifold instrumental aids that modern science has provided.

If we, by any and all means now at our disposal, begin the work of chemical decomposition of any of the natural bodies, whether animal, vegetable or mineral, we obtain gradually more and more simple products; but the further we proceed in this work of chemical analysis, the more individualized appear the resulting components. Finally, when all the methods for chemical decomposition now at our command have been exhausted, we arrive at a number of most thoroughly individualized and permanent substances, which thus far have resisted all attempts at further decomposition; these substances are known as the Chemical Elements.

A chemical element is a substance which, thus far, has not been decomposed.

This our definition is now* gradually supplanting the older definition implying the *impossibility* of the further chemical decomposition of these elements. It is of course very risky for any one man to assert that to be *impossible* which he himself is unable to do; but it is equally risky for any one generation to assert all that to be impossible which it is unable to do.

Only a century ago, it required weeks to cross the Atlantic; and no news, no letter, could be transmitted between Europe and America faster than the wind would blow the best constructed

---

* Traube, Physik. Chemie, Stuttgart, 1904, p 27.

sailing vessel, directed by the most skillful captain, across the ocean. Then the time of transmission was shortened by the introduction of steamships; next by the submarine cable and now the wireless flashes intelligence between shore and ship in mid-ocean and even across the broad waters.

As a matter of history, many substances have, at some given time, been classed as chemicial elements, which now are known as chemical compounds. Lavoisier counted the alkalies and earths rightly as chemical elements; since Davy decomposed them by the galvanic current, we know them as chemical compounds, conform to the supposition of Lavoisier.

These chemical elements are necessarily the most important of all substances to the chemist, for all existing matter is simply one or another of the infinite number of combinations or chemical compounds of these elements. For that reason the physical and chemical properties of the elements have been one of the most important fields of study for the chemist.

But not all properties are of equal importance or equally characteristic. The most important physical properties of the chemical elements are *three*, namely, the *specific gravity*, the *fusing* and the *boiling point*. We shall in the sequel represent the numerical value of these by the letters G, F and B. Together these three constitute the *physical characteristic* of an element.

Since these properties have definite *numerical values* (i. e., are *quantitative* properties), we can represent them graphically to the eye — and thus may be enabled to compare one element with another most readily and most absolutely.

Indeed, by this means we may temporarily leave out of consideration all properties manifestly of secondary value, such as color, odor and the like, and represent the most characteristic properties, or *the real quantitative essence of the different elements by a system of points in space*, each point representing the three most characteristic physical properties exactly in quantity by its three co-ordinates.

Such a *graphical representation of a number of chemical elements* is presented on plate 1.

The elements themselves are designated by the *chemical symbols* introduced by the founder of modern quantitative chemistry, *Berzelius*, in 1815, and which have been used by the chemical world ever since. These chemical symbols are composed of the *initial* and the *most characteristic letter* of the latin or latinized *name* of the chemical element.

The latin names of iron, silver, gold are ferrum, argentum, aurum; hence the corresponding chemical symbols are Fe, Ag, Au. Zinc is latinized zincum; symbol Zn. Magnesium is designated by the symbol Mg while Manganese is represented by Mn. But we suppose the reader to be familiar with this part of chemical notation.

The three characteristic properties G, F, B are in our chemical books recorded in tables, and expressed in numbers. The numerical unit for all these properties is taken from the substance water. The specific gravity of any substance being the weight in grammes of one cubic centimeter of the substance; the specific gravity of water is one because the metric system takes as the unit of weight (the gramme) the weight of a cubic centimeter of water. Again, water has been adopted as the standard substance for temperature determinations; namely its freezing point is marked zero, its boiling point 100. Thus, both F and B are numerically determined on this thermometric scale as the *degree* (or number) at which the solid changes to a liquid and the liquid (under the pressure of one atmosphere, 760 millimeters of mercury) boils freely.

In plate 1 we lay off the *fusing point*, F, from left to right, the *boiling point*, B, from below perpendicularly upwards. The *specific gravity* G is supposed to be laid off from the front to the rear *horizontally;* but in our diagram we show it in the plane by an old form of perspective, under an angle of 45 degrees or half a right angle. The words followed by an arrow, show how these three numerical values F (to right), B (upwards) and G (backwards) are drawn *from the lowest left hand point* of the diagram, which represents the ABSOLUTE ZERO OF TEMPERATURE (i. e., 273 degrees Centigrade below the freezing point of water) and the *specific gravity zero.* That point is the *zero point* for the three co-ordinates F (to right), B (upwards) and G (backwards, represented in perspective).

We invite the reader to trace this graphical representation of the characteristic properties of a few of the best known groups or families of chemical elements. The *trace* had been drawn on the horizontal plane (F, G) and by verticals equal to the boiling point (B), the *single point in space representing each single element* is determined and marked by its *chemical symbol*. These points are joined by *straight lines* and the vertical planes so formed are *shaded* by perpendiculars joining the line of points (*open circles*) representing the element with the line of points (*black circles*) representing only the two properties (F, G) on the horizontal plane. By looking at this plate carefully with *one* eye only (the other being closed) the broken series of vertically shaded plates will appear standing out plainly from the horizontal base F, G.

For example, the three elements, Chlorine, Bromine and Iodine are known to most closely resemble one another chemically, so much so that chemists for about a century have considered them to form a *related group* or *family* of chemical elements; they have been called salt-formers (or *haloids*). But not all their compounds are salts, and many more compounds are true salts that do not contain either of these elements. For that reason we prefer to call this family by the name *chloroids*, which simply asserts that they are chemical elements closely resembling chlorine in their essential properties.

On the horizontal co-ordinate plane F, G, the *three points* representing these two properties for the chloroids, indicated by the full-shaded black circles designated Cl, Br, Io, *are seen to lie exactly in a straight line*. Since now any *two* points determine a straight line, the fact that the *three* points representing the *two properties* (G, F) of each one of these *three elements* (Cl, Br, Io) form *one* continuous straight line, *proves mathematically* (here geometrically) *that these three elements are related to one another in some way* in their essential nature or composition. They surely are *not* strangers, independent bodies, composed of entirely different materials.

From each point (G, F) on the horizontal plane the boiling point (B) has been set off on its vertical; the terminals are marked by *open circles* and by the chemical symbols Cl, Br, Io.

Here again we notice that *the three points* (open circles) marked Cl, Br, Io, *lie in a straight line*, and in this case the mathematical fact is a much more rigid one than in the first, because the angle formed towards the fusing point line on the horizontal plane F, G, is much more steep than the angle of the latter towards the specific gravity axis.

As a final result, we find that *the nine individual determinations* of the specific gravity, fusing and boiling point of each of the three chloroid elements *are not independent quantities*, *but are mathematically related* in such a manner, that the three points (each representing the three properties G, F, B) *form a straight line in space*, which fact is the *geometrical expression* of that mathematical relation.

Another group of related chemical elements we have in the three elements: sulphur, selenium and tellurium, which for convenience we term the *Sulphoids*, that is, elements closely resembling sulphur. On the horizontal plane, F, G, the three shaded or *black circles* marked S, Se, Te, form approximately a straight line. Setting off on perpendicularly the observed boiling points, we find the *open circles* representing the three fundamental properties for each of these sulphoids, again in a straight line. The boiling point of tellurium (abt. 1400) falls beyond the margin of our plate, but the direction drawn on our larger plate is shown here.

The two families of chemical elements considered, being destitute of metallic properties, are commonly called *Metalloids*. We will now also examine some of the *metals*, that is chemical elements possessing metallic luster and malleability and also generally being good conductors of heat and electricity. The metalloids form a notable contrast with the metals, not only in the above properties, but also in others, that will be considered further on.

First we will notice the three full circles marked Hg, Cd, Zn, the horizontal plane F, G, showing that the fusing point diminishes nearly proportional to the increase of the density — the very opposite of the course shown for the metalloids of the chloroid and sulphoid groups. Setting off the boiling point on perpendiculars we notice the three points again in a straight line approximately, but also lowest for the heaviest metal, that is *reversed in direction* as compared to the metalloids above considered. This group of three metals we call the *Cadmoids*, since both Zinc and Mercury closely resemble the middle member of the group.

On this diagram we have entered the characteristic properties (G, F, B) in the manner stated (as co-ordinates) for the five elements, Nitrogen, Phosphorus, Arsenic, Antimony and Bismuth, which in all works on chemistry for nearly half a century have been described as belonging to one group or family of elements; we have called this group the *Phosphoids*, that is elements resembling phosphorus.

Of these five chemical elements, the first two (N, P) are decidedly metalloids, while the last two (Sb, Bi) are decidedly metals in every respect but that of malleability. In this regard antimony and bismuth are not malleable at common temperatures, but *brittle*, and sufficiently so that they may be readily pulverized in a mortar. Futhermore, we find nitrogen to be a gas, so difficultly liquefied that it was classed as one of the few "permanent gases" that up to 1877 had not been liquefied. Assuredly this group of chemical elements, the five phosphoids, comprises elements of striking variation in their characteristic physical properties. It will therefore be most instructive to trace their place in our diagram.

We notice, first, that the black dots marking the fusing points (as related to specific gravity) on the horizontal plane F, G, *form an approximately straight line* for the first four elements N, P, As, Sb. But it must be borne in mind that arsenic is so volatile that it disappears on gentle warming in the open air without fusing; only when heated under pressure does it exhibit fusion, for pressure *increases* the boiling point much more rapidly than the fusing point.

Erecting perpendiculars to set off the boiling points, we find the points N, P, As, Sb, marked by *open circles*, approximately in the one vertical plane P, Sb. They form a broken line, in which P is about as much *above* as As is *below* a straight line drawn from N to Sb.

On the whole, this feature corresponds to the chloroids and the sulphoids, that is to the metalloidic elements. If we now from Sb pass to Bi, we find that the fusing point greatly lowers with increasing gravity, while the boiling point continues to rise with increasing gravity. In other words, compared to the first four phosphoids N, P, As, Sb, the *fifth* Bi in its fusing point changes like the metals, while in its boiling point it follows the habit of the metalloids thus far studied. The boiling point of bismuth is not marked on plate *1* except by the direction of the arrow upwards and to the left from Sb; it boils about 1600 degrees, which falls beyond the range of our plate.

The peculiar properties of the five phosphoid elements furnish sufficient reason for the fact that the first two (N and P) by all chemists are classed as metalloids, while the last three (As, Sb, Bi) have quite generally been called semi-metals (Halb-Mettalle in German). The Alchemists were well acquainted with this peculiar group of metals.

On our plate will also be found three representatives of the *Metals of the Alkalies*, namely Li, Na, Ka. Since such a name is too cumbrous for practical use, we have substituted the term *Kaloid* for the same, which merely implies that these metals closely resemble Ka (Kalium), that is Potassium.

It will be remembered that we can represent the *three* co-ordinates (G, F, B) on the plane of a diagram only by means of some sort of perspective drawing, which involves more or less distortion. The mode of perspective selected by us and used in the diagram we have thus far studied, gives the two temperatures (F and B) in true dimensions, without any distortion, but the specific gravity G then necessarily is greatly distorted in direction.

If we would have the entire representation *without distortion* we must make *three drawings instead of one*, namely one each for the three co-ordinate planes G, F; F, B and G, B — and then *mentally combine these three;* or we must *represent them in a bodily model.*

Such a model can be readily constructed by taking plane G, F as the base, and erecting perpendiculars of proper lengths (say of wires or wood) inserted in the points marking the fusing point. The *lines in space* then can be marked by wires, threads or narrow ribbons of different colors. Such a model shows almost at a glance many general laws of great importance that have been entirely overlooked by chemists who have merely put the observed data in columns of printed tables in their books.

Plate 2 gives the base for such a model; it represents the gravity and fusing point, that is the plane G, F. We have also added *our symbol for the genera* or groups *of chemical elements*, namely the *Greek* letters corresponding to the *Latin* introduced by Berzelius for the individual elements.

Since for typographical reasons we cannot insert these our Greek group-symbol, in the *text*, we have marked them on the *plates* only. The symbol for the chloroids is pronounced *chi*, for the sulphoids *theta*, for the phosphoids *phi*, for the cadmoids *Kappa-delta*, and for the Kaloids *Kappa-alpha*.

In this plate both specific gravity and fusing point are represented without distortion. We notice the *Chloroids* (Cl, Br, Io) and *Sulphoids* (S, Se, Te) as well as the first four *Phosphoids* (N, P, As, Sb), showing that *the fusing point rises with the specific gravity*, which we above have found to be a peculiarity of metalloids. The three *Cadmoids*, Hg, Cd, Zn, show the opposite character, their line of fusing points standing almost at right angles to that of the metalloids just specified.

Modern chemists quite generally include magnesium (Mg) and Beryllium (Be) with the above Cadmoids; our diagram shows that the line of fusion continues downward and almost in the same direction from Zn to Be as from Hg to Zn.

On this chart it has been possible also to locate the metals, Copper, Silver and Gold, which we designate as *Cuproids*, i. e., Copper-like metals. It will be noticed that the *line of fusing points* of the cuproids neither goes down with decreasing specific gravity as for the metals, nor up, as for the metalloids; *in fact it remains very nearly the same* for Cu, Ag and Au, although the specific gravity varies more than in the ratio of one to two.

This fact should cause us to think twice before we generalize our conclusions, making the contrast between metal and metalloids. *Surely the Cuproids possess the physical properties of the metals* in the highest degree. We must therefore inquire what may be the cause here involved, marking the contrast between, say, Chloroids and Cadmoids, with Cuproids as the connecting link.

A moment's consideration will suffice to recognize that metals are of two kinds in their electrical character, as determined by their deportment in the electrolysis of their compounds. We may be pardoned to retain the nomenclature of the founder of quantitative chemistry and really also of electrochemistry; we shall, then, with *Berzelius*, continue to call that constituent *electropositive* which in electrolysis *appears at the negative electrode*, and shall likewise call that constituent *electronegative* which in electrolysis *appears at the positive electrode.*

Now, the cadmoids are pronounced electropositive metals; so are still more, the kaloids. The metalloids are electronegative; the cuproids are comparatively neutral.

Accordingly we may express the rules above stated, defining the relation of the fusing point to the specific gravity, in the following manner: —

1. The fusing point of pronounced *electronegative* elements *increases* with their specific gravity. Examples: the Metalloids; Chloroids, Sulphoids.

2. The fusing point of pronounced *electropositive* elements *diminishes* with increasing specific gravity. Examples: Cadmoids, Kaloids.

3. The fusing point of *intermediate* (relatively neutral) elements does *not vary notably* with their specific gravity. Example: Cuproids.

THE BOILING-FUSING POINTS.

It will also prove very interesting and quite instructive to study our plane B F, that is the fusing-boiling points of the elements. Here *each element* (or generally substance) is again represented by *a single point*, the abscissa of which is the *fusing point*, while the ordinate is the *boiling point*. Of such diagrams my chemical atlas (size double elephant drawing paper) contains a number; plate *3* is a *greatly reduced* copy representing the boiling-fusing points of the chemical elements.

The origin is the absolute zero, but the temperatures are plotted by the more convenient centigrade degrees, thousand degrees to 71 millimeters. The fusing points covered by this plate reach about 1100 C., the boiling points about 1600 C., so that the total range for these (from absolute zero) is about 1400 and 1900 degrees. For a number of very interesting elements, the boiling point falls above the limit of the plate; if the fusing point is known and below 1100 degrees, it is entered on the 1500 degree line, and marked by an arrow pointing "upwards" towards the boiling point beyond the limit of the plate.

I do not know that such charts or diagrams have been used by others in the study of the change of state of aggregation of chemical compounds and elements; but I know that such diagrams have aided me greatly in the study of the mechanical conditions of the change of state of aggregation, which investigation has been carried on by me for many years, as evidenced by my list of publications.

We see here at a glance (plate 3) that the boiling-fusing point curve for the chloroids and kaloids is a straight line, also for the first four phosphoids; that it is approximately a straight line for the sulphoids and cadmoids. These *groups of elements* are designated near the curve by our *Greek symbol* of the same, while the *individual elements* are designated by their chemical symbol introduced by Berzelius. The boiling-fusing point of nitrogen is a little below the straight line determined by Sb—P; but the boiling-fusing point of fluorine has been found a corresponding small number of degrees above the straight line determined by Cl—Br—Io. Finally it will be noticed that the boiling-fusing point of hydrogen is quite near the absolute zero.

It is very much to be regretted that experimental determinations are still very incomplete, allowing us only to represent about half a dozen genera (or families) of chemical elements on this diagram.

The angle under which the straight line or nearly straight line of boiling-fusing points of a genus of elements inclines towards the horizontal (abscissa) marks the ratio at which boiling and fusing points increase for a given genus or group of elements. Thus, for the chloroids the angle is near 45 degrees, showing an approximately equal increase in both temperatures, while for the sulphoids and kaloids the angle is nearly 70 degrees, showing that the change in boiling point is much greater than the corresponding change in fusing point.

But this is not the place to enter upon the finer details, though they are exceedingly important and interesting; they must be looked up in our special publications on this subject. Here we merely intend to present a popular outline of our results.

In this connection we may also state that we do not want to present the numerical data — which may be found in any modern work on chemistry or physics — but we present these data in graphical form, in diagrams, most carefully and accurately constructed on a large scale, using ordinarily a sheet of the size known as double elephant; from these large and accurate drawings, the cuts inserted in this work have been obtained by photography. They are therefore almost microscopically exact.

Again for a moment returning to the consideration of our plate 3, we notice, by the chemical symbols inscribed near the points in the boiling-fusing point lines, that

1. For electronegative elements (Chloroids, Sulphoids) the boiling-fusing point lines run *upwards* with increasing density; while

2. For pronouncedly electropositive elements (Kaloids, Cadmoids) the boiling-fusing point line runs *downwards* with increasing density.

The intermediate class of chemical elements (Cuproids) are not represented on this diagram, because their boiling points fall beyond the limits of this plate, and are not known with sufficient precision.

THE ATOMIC WEIGHTS OF THE ELEMENTS.

Thus far we have exclusively used the three fundamental characteristics G, F, and B of the chemical elements. These three are all truly physical properties. We have, however, grouped some of the elements in accordance with the chemical experience of almost a century. As examples we refer to the chloroids, the kaloids, and other groups of elements specified.

But it is well known that the physical characteristic (G) called the specific gravity is variable with temperature, usually diminished as the temperature increases.

Accordingly it may not bring out the true relations in the most perfect manner. Thus in our diagram *Plate 1* we find the fusing points of Cl, Br, Io apparently in a straight line. But when the same data were constructed without the angular distortion of perspective (see Plate 2), we notice a slight break in the line Cl—Br—Io. Now the question arises: is this slight difference in the direction Cl—Br from that of the direction Br—Io real, or is it merely apparent, due to the above admitted variation of the specific gravity with temperature?

In earlier efforts on this ground attempts have been made to apply corrections to the values of specific gravities or to reduce the same to some definite degree of temperature, or to some temperature a certain number of degrees distant from the fusing point. All such endeavors are unsatisfactory, because they introduce new unknown or uncertain data.

But chemists know that the physical property called the specific gravity for related chemical elements varies with the *atomic weight* of such elements; and since this atomic weight is entirely independent of temperature and other physical conditions, it appears desirable to introduce the same in place of the specific gravity in charts for the study of boiling and fusing points of the chemical elements.

We therefore must try this method of comparison, i. e., the replacement of the somewhat variable specific gravity by the invariable atomic weight of the chemical elements.

But if we turn to the more recent chemical publications we find that *the atomic weights of the chemical elements* have become entangled in the meshes of authority and technicality. In the United States, the Smithsonian Institution has put its stamp of authority upon a set of values professedly calculated with great mathematical precision. These American Government authorities (for the professed calculator is an officer of the Department of the Interior) have combined with the American Chemical

Society and with certain representatives of the German, English and French Chemical Societies, in issuing annually a set of *International Atomic Weights* for the universal use of the chemists of the world.

These so-called international atomic weights have not been universally adopted by the chemists of the world. The fixing of definite scientific values by agreement of certain so-called international authorities seems to be as futile to-day as corresponding decrees on scientific fundaments have proved themselves in former centuries.

We only mention these facts and circumstances here at this point to advise the reader that we, in this our study, cannot use these so-called international atomic weights because we have found them to be not true to nature, but incorrect and false in most essential particulars.

We shall substantiate this statement in the closing part of this small work; here it will be perfectly sufficient to use our own *atomic weights*, *which are essentially the same as those in common use before this official declaration of natural values was undertaken.* This is so much the more proper, as the differences between or own (or the old) atomic weights and the so-called international atomic weights are *numerically* so small as not to affect the results of our conclusions in this present research.

Since these so-called international atomic weights are being used to support a false chemical principle and since they have been proved to be false in themselves, it will be impossible for us to use the same. See our "True Atomic Weights," 1894, and especially our "Absolute Atomic Weights," 1901.

The atomic weights are supposed to be implicitly represented in the symbol of the chemical elements. We give a few examples: H, 1; O, 16; C, 12; Li, 7; Na, 23; Ag, 108; Fe, 56; Ca, 40; As, 75; N, 14; etc., etc. We do not need to burden these pages with a full table of atomic weights.

We will merely add, for information, that for the above elements, the so-called "international atomic weights" proclaimed for the year 1902 were in the order above used: 1.008; 12.00; 7.03; 23.05; 107.93; 55.9; 40.1; 75.0; 14.04. What the precise values decreed for 1904 may be, I have not taken the trouble to look up, for the pretendedly ascertained and proclaimed *small differences* of these so-called international atomic weights from the old or common atomic weights above given and here to be used, are insignificant for our present and for most practical purposes.

Taking now the *common atomic weights* as abscissae (instead of the specific gravity) and the *temperature* in Centigrade degrees as ordinates, we obtain the diagram Plate *4*, in which the *fusing points* are marked by full, black circles, and the *boiling points* by open circles. It might have been advisable to represent these two values, B and F, on two distinct diagrams; but our diagram giving both, while a little more complex, has the great advantage of permitting a direct comparison of the course of fusing points with that of the boiling points for any group of chemical elements.

Our diagram, Plate *4*, graphically represents the *Boiling and Fusing Points of the Chemical Elements in Relation to their Atomic Weight.* The temperature runs up from the absolute zero to 1600 degrees Centigrade, and the atomic weight from zero to about 230. The temperatures of 0, 500, 1000 and 1500 degrees are marked, also the atomic weights 0, 100, 200. The original drawing was made most carefully on a half-sheet of double elephant drawing paper, and reduced photographically to ths diagram here inserted, which therefore is almost microscopically exact. It will bear the use of an ordinary magnifying glass. It will be advisable to study first the *fusing point lines* (black circles) and thereafter the *boiling point lines* (open circles); for the former are necessarily most complete, since many boiling points fall above the limit of our diagram.

FUSING POINTS AND ATOMIC WEIGHTS.

First, we notice the fusing line of the chloroids Cl—Br—Io to form practically a straight line; the fusing point of Br being but very little below the straight line joining Cl and Io, so little that it takes a good eye to see the slight break at Br.

Second, for the denser and less volatile sulphoids the deviation of Se from the straight line indicated by the points S—Te is considerable. The fusing point of tellurium is considerably higher than would be indicated by the prolongation of the straight line S — Se.

Third, for the corresponding phosphoids P—As—Sb the deviation is in the opposite direction, for the fusing point of Sb lies below the straight line drawn from P to As and continued.

For all these elements (chloroids, sulphoids, phosphoids) the fusing line runs obliquely upwards.

The steepness, or the angle formed between the fusing line and the horizontal is least for the chloroids, greatest for the phosphoids, intermediate for the sulphoids. In other words, while *the fusing points for all these groups* INCREASES *with the atomic weight*, this increase is greatest for the phosphoids, least for the chloroids and intermediate for the sulphoids, for an equal increase of the atomic weight.

This is a most remarkable fact which immediately suggests a *relation to the chemical valence* of these elements. It will be remembered that one atom of chlorine is saturated by *one* atom of hydrogen, but that the saturation of one atom of sulphur requires *two* atoms of hydrogen, while one atom of phosphorus requires *three* atoms of hydrogen for saturation.

Accordingly, the *valence* of the chloroids is *one*, that of the sulphoids is *two*, while the phosphoids have the valence *three*. This is manifestly the order of steepness of their fusing point line brought out by our diagram.

Taking, as a first approximation, the straight line determined by the *first and last* of the three elements of each of these groups, a simple measurement on the original drawing gives for the angle of elevation in question the following values, in degrees:

Chloroids 25; sulphoids 36; phosphoids 53; for which the natural tangents are respectively 0.47, 0.73 and 1.33, which means:

For an increase of one hundred in the atomic weight, the fusing point rises for chloroids 47 degrees, for sulphoids 73 and for phosphoids 133 degrees.

If we *divide* this rise by the valence of the element, we obtain *per hundred atomic weight and per valence one* an *increase of the fusing point* of

47	degrees for	chloroids,
36	" "	sulphoids,
44	" "	phosphoids.

These values are nearly equal, when we consider that we have taken only the general trend of the fusing point lines as marked by the first and last members of these groups of three elements — the *triads* of Doebereiner, 1829.

The mean of these values is 42. Our diagram therefore proves that *the fusing point of the most electronegative elements rises about 42 degrees for each unit of valence per one hundred units of the atomic weight in the triads* Cl—Br—Io; S—Se—Te; P—As—Sb.

If we now look *below* and *above* these middle terms — the old triads — we find most important new facts.

First, the line from Cl, S, P to the initial element (Fl, O, N) of the genus or family considered, is not in line with that of the triad, but *very much steeper*, showing a sharp break or elbow at the first element (Cl, Br, Io) in the triad.

This mathematical relation exhibited geometrically in our graphical representation demonstrates with absolute certainty that the starting member of a genus *is not in its composition or structure identical* with the next three members which constitute the old triad.

It is true, our diagram gives only the exact location of the fusing points of hydrogen and nitrogen; but we know that the fusing points of oxygen and fluorine are within the small area determined by these two, which fact is sufficient to fix the direction of the lines from P, S, and Cl in question, and which lines are properly dotted on our diagram for S and Cl while the line from P to N is drawn and in full, having been experimentally determined when the diagram was drawn by us. To-day, the experimental data for the others also having been determined, we might enter the same on a new diagram; but it is evident that it would produce no visible difference on the resulting new chart. We have neither the time to make such new chart nor the money to pay for a new cut that is not necessary.

Next we will look at the related element beyond the triad. Here we find only one case, namely bismuth of the phosphoid group, for the long espected heavier fifth element of the chloroid and sulphoid groups have not yet been found.

The fusing line Sb—Bi is seen to turn downwards, almost at right angles to the general direction of the fusing line P—Sb. My original drawing shows this angle to be 89 degrees.

The diagram Plate *4* shows the fusing line Sb—Bi of the phosphoids to be exactly parallel to the line Cd—Hg of the cadmoids; on my original large drawing this parallelism obtains perfectly when tested by proper means.

This fact not only proves again the metallic character of the last two phosphoids, but also shows that the constitution of Bi must differ from that of the triad P, As, Sb.

Passing now to the consideration of the fusing points of the metals, we naturally begin with the most marked of all metallic genera, the most electropositive of all elements of lowest valence (one) of all, also the most volatile and fusible of all metals, finally the lightest of all metals, the *kaloids:* Li, Na, Ka, Rb, Cs. This genus or family of elements is as absolutely fixed and limited as that of the monovalent, most electronegative metalloids, the chloroids.

Our diagram shows that the fusing point line sets in highest with lithium, and gradually runs down to the lowest fusing point of the heaviest cesium. While the total range in fusing point for the kaloids is much less than that for the chloroids, there can be no question about the fact that it runs in the opposite direction: *falling instead of rising* with increasing atomic weight.

The *divalent metals* form the genus of cadmoids, comprising Be, Mg, Zn, Cd, Hg. The range in fusing point is much greater, the fusing point line running down much faster from Be (about 1000 degrees) to Hg (below zero).

The line shows plainly *two* divisions, namely the steepest descent from Be to Zn, followed by a much more gradual descent from Zn to Hg.

The *trivalent genus* Bo, Al, Ga, In, Tl which we have called the *styptoids* after aluminum, starts its fusing point line with *boron* beyond the field covered by our chart, above 1600 degrees, falls most rapidly down to Mg (about 700) drops once more to Ga and then leisurely rises over In to Tl.

The *tetravalent genus* C, Si, Ge, Sn, Pb which we have called *Adamantoids* after the diamond, shows a similar fusing point line.

That the *descent of fusing point* for the metals is related to the *valence* in a like manner as we found the *ascent of the fusing point* for the metalloids there can be no question, for the diagram shows it unmistakably; the descent is slowest for the monovalent, much more rapid for the divalent and most steeply descending for the tri- and tetravalent elements.

In the main, the numerical relations may also be detected. The line Li—Na meets the base under an angle of 49.5 degrees, the tangent of which is 1.15. The line Be — Zn, on which Mg is found, meets the base under the angle of 63.5 of which the tangent is 2.00. This is sufficiently near the proportion of 1 to 2 of the valence for kaloids and cadmoids, considering the intricacy of the problem.

For the next two genera of elements the conditions are more complex. The first element of the divalent cadmoids is still properly a metal, namely, Beryllium. But the first member of the trivalent genus is Boron, of the tetravalent it is Carbon, and neither of these elements can be considered metallic in character. Only the second member (Al, Ge) may be taken as metallic.

Now, as we found a change in fusing point relations when from metalloid we passed to metallic members in the electronegative genera, so we must expect here varying relations where we pass from the metallic to the truly non-metallic electronegative elements.

Nevertheless, the effect of valence on fusing point variation is plainly marked, as the following facts will show.

For the *trivalent elements*, the inclination Bo—Al to the horizontal being 85 degrees, the tangent of which is 11.4, shows plainly a transition. Taking the next member, the line Al—Ga inclines at 73 degrees, of which the tangent is 3.27. This corresponds to Mg—Zn, which inclines 63.5 degrees, of which the tangent is 2.00.

For the *tetravalent elements* the inclination C—Ge to the horizontal is 78 degrees, of which the tangent is 4.7. But for the second-third elements Ge—Sn the inclination 63 gives only 1.96 as tangent; evidently we get here no comparable result, tin being too different from Carbon and Germanium; some chemists even doubt its place in this genus.

Making all due allowance for the influence of the transition from true metals to metalloids, we can tabulate the *fall* of the fusing point for an increase of hundred units in the atomic weight for the first members of the four genera of electropositive elements in the following manner: —

Valence,	1	2	3	4
Fall degrees,	115	200	327	470
Per unit valence,	115	100	109	117

The mean of these values is 110 degrees, which may be taken as the fall of the fusing point per unit of valence produced by a rise of one hundred units in the atomic weight for the first members of any one genus of the electropositive elements.

The corresponding rise for the middle triad of the electronegative genera of elements we found to be 42. But strictly this rise cannot be compared in amount with the fall for the *first* members of the electropositive elements.

Our diagram gives the fusing point line N—P from observation; this only is comparable to the fall for the electropositive elements. Let us determine it.

Direct measurement on our original drawing shows that the line N—P forms an angle of 73 degrees with the horizontal; the tangent hereof is 3.27, giving a rise of 327 degrees in fusing point per hundred increase in atomic weight. Since these elements are trivalent, the rise is 109 degrees per unit valence.

This agrees with the corresponding fall for the electropositive elements, being in fact identical with that for the elements Al—Ga.

We may now consider the course of the fusing point lines for last members of each of these genera of electropositive elements. For the Kaloids and Cadmoids we have already traced the continuous obliquely downward course of these lines. But the other two lines terminate in an *upwards course* forming an elbow respectively at Ga for the Styptoids and at Sn for the Adamantoids. We also notice that this rise is not greatly different from that of the chloroids, though somewhat less. The lines Sn—Pb and In—Tl are practically parallel. Also In—Tl is practically perpendicular to Al—Ga.

This corresponds exactly to the turn under a right angle of Sb—Bi to P—Sb, brought out when we studied the fusing point lines of the metalloids.

Measurement gives the inclination of the line Sn—Pb 17 degrees, while In—Tl is found to be 14 degrees, the mean is 15.5 degrees, of which the tangent (i. e., rise per unit) is 0.28. The number of degrees the fusing point rises for these metals for an increase of hundred units of their atomic weight is therefore 28.

Finally our chart shows the fusing point lines for two triads of intermediate elements or metals, namely the Cuproids and Palladoids. These, as stated before, show no great change in fusing point; the line Cu—Au rising at an angle of 1 degree only, corresponding to a change of only 2 degrees in the fusing point per 100 atomic weight.

To complete the inquiry, we find the rise of the line Ag—Au 14 degrees, the tangent of which is 0.25. Thus from silver to gold the fusing point rises 25 degrees per hundred increase in atomic weight. This line is exactly parallel to the line In—Tl and differs but little in direction from the line Sn—Pb (incl. 17 degrees, tangent 0.31) and Pd—Pt (incl. 18 degrees, tangent 0.33).

But while the terminal part of these lines, closing with the element of highest atomic weight, are nearly parallel, thereby showing rise of between 25 and 33 degrees in the fusing point for an increase of 100 in the atomic weight, the preceding line meets this terminal line under a very different augle.

Our diagram shows the angle at Pd and Ag to be quite obtuse — about 150 degrees at Pd, 141 degrees at Ag; at Sn the corresponding angle is 110 only. These facts amplify the evidence obtained before showing that the cuproids, being electrically intermediate, must be considered as forming an intermediate and distinct division of the elements. The palladoids here show themselves to possess the same characteristics in their fusing point line both as to position (high up) and as to form (nearly a straight line).

Before passing to the consideration of the boiling-point lines represented on this diagram, we shall sum up the general facts ascertained for the fusing-point lines.

1. *The fusing-point line* for any one genus of chemical elements consists of three distinct parts, namely: —

an *initial part*, very steep;
a *middle part*, moderately inclined;
and a *terminal part.*

2. For the *electro-negative* elements (metalloids), the fusing point line *rises*, for the pronounced *electro-positive* (metallic) elements it *falls* with increasing atomic weight, while for less pronounced elements (like the cuproids) there is but a moderate change.

3. *The initial part* shows an almost equal change — rise for metalloids, fall for metals — for a unit of valence and per hundred increase in atomic weight.

4. For *the middle part* — the old triads — the change per unit valence and hundred units of atomic weight is also the same, but less than half the initial amount.

Now, turning to the consideration of the *boiling point lines*, we first notice with regret the paucity of material at hand, largely due to the generally high boiling points of the majority of the elements, which have offered great obstacles to experimental determinations. Possibly the recently introduced method of boiling metals in an almost absolute vacuum may yield valuable data, if strictly comparable conditions can be secured.

From the data at hand when our diagram *Plate 4* was drawn, we have only constructed the lines for the Argonoids, Chloroids, Sulphoids, Phosphoids, Kaloids (very incomplete) and Cadmoids.

First, we notice that boiling point lines of the Kaloids and Cadmoids *show the same contrast* with that of the electro-negative metalloids as did the fusing point lines: *rising* with increase of atomic weight for the metalloids, *falling* for the metals.

Second, we see most markedly the *initial* and *middle* part of these lines to be totally distinct, the first much more steep than the second. This feature is even shown by the nullovalent elements, the argonoids.

The following table shows the principal results that may be read off from our diagram:

Genus.	Part.		Inclination.		Tangent.
Argonoids:	Initial,	He—Ar	ca. 25	degrees	0.47
	middle,	Ar—Xe	12	"	0.21
Chloroids:	initial,	Fl—Cl	60	"	1.73
	middle	Cl—Io	26	"	0.49
Sulph-Phosphoids	initial	N—P, S.	83	"	8.14
	middle	P, S—Sb, Te	70	"	2.75
	terminal	Sb—Bi	34	"	0.67
Kaloids:		Na—Ka	41	"	0.87
Cadmoids:	middle,	Zn—Hg	41	"	0.87

For the phosphoids and sulphoids we have taken a middle value, the two lines rising almost in the same manner.

The following are the most notable conclusions that may be read from the values just given. It will be borne in mind that the tangent represents the rise per unit, so that the rise per hundred is obtained by moving the decimal point two places to the right. For the middle of the argonoids the diagram shows the line to be inclined under 12 degrees to the horizontal; the common tables show the tangent of 12 degrees to be 0.21; consequently the boiling point rises 21 degrees per hundred units increase of the atomic weights for argon to xenon.*

1. *The boiling point rises the least for the argonoids, which are nullovalent* (valence zero). This rise is only 47 degrees per hundred atomic weight for the initial part, and less than half that amount (21) for the middle part. 2. The *middle line of the monovalent chloroids* rises as much as the initial part of the nullovalent argonoids (about 48 degrees per hundred increase of atomic weight). 3. The strange fact that the rise for sulphoids and phosphoids is so closely alike throughout both genera, may be connected with their so-called abnormal vapor densities at the boiling point. *Troost*† considers sulphur vapors at this point comparable to ozone — which would explain the equality of the rise for divalent sulphur to that of trivalent phosphorus. We might actually repeat the words which *Troost* (l. c.) uttered a quarter of a century ago: "This, it seems to me, is the "closest analogy that can be invoked to reconcile facts of this "nature."

Final Conclusions.

Passing into review all facts and general relations between boiling and fusing points on the one hand and atomic weights on the other, we must draw the following general conclusions: —

Both the fusing and the boiling points of the chemical elements are manifestly dependent upon the atomic weight of the same; but that relation, while strongly marked, is not expressive by the common "rule of three," nor can these points be said to be even increasing with the atomic weights, for the *very sign* of the variation changes, being *positive* for metalloids, and negative for strongly pronounced electropositive metals, while for the least

---

* While reading this proof we obtained the fusing points of the higher Argonoids from the Catalog (British Exhib. Group 23) and have entered them on our large original drawing.

The fusing point line practically coincides with the boiling point line at argon, and forms an angle of about 4 degeees below the latter.

The fusing point of the argonoid triad rises therefore only 11 degrees per hundred increase of atomic weight.

† Comptes Rendees, T. 86, p. 1396; 1878.

volatile and fusible metals the entire influence of atomic weight is relatively small.

While the *direction* of the change varies with the electric character of the element it appears that the *amount* of the change, for pronounced electropositive or electronegative elements is approximately equal for the same increase in atomic weight, *not* of the element itself, but *for a unit of valence* of the same.

Finally, all these remarkable relations — most of which have been brought to light by our method of graphical research here used — make it impossible to look upon the chemical elements as unrelated, independent substances, for these mathematical relations (here expressed geometrically) are inconceivable on any supposition but that *all chemical elements are compounds* of groups or links, of one and the same material united according to apparently very simple and very few modes of combination.

The last clause of our conclusion is based upon the facts above established that: —

First, in each genus of elements we can distinguish a front, middle and last term, the middle consisting of three elements, a triad.

Second, the *sign* of increase is positive for electronegative elements, and negative for pronounced electropositive elements, while the *amount is roughly the same for both per unit of valence.*

Third, for elements (metals) of no pronounced electric character, the change is neither positive, nor negative, but quite insignificant either way.

FUSING POINT AND VALENCE.

The somewhat detailed exposition of the relations of the fusing point of the chemical elements to their atomic weight has shown that *the valence and electrical character* of the elements are really determining the character and amount of the influence of the atomic weight itself. It may therefore be advisable to consider these most fundamental effects of valence and electrical character once more and, as it were, independent of the atomic weight as such. This apparently impossible condition we can readily fulfill by considering the *genera* as such, arranging them according to valence and tension (if we may use this term for brevity's sake). This is precisely what we have been publishing since 1867, and what constituted the basis of our Natural Classification of the Chemical Elements. The history of this classification is given in our True Atomic Weights, 1894, pp. 227–239.

In Plate *10* the data of observation have been graphically represented in our usual manner. The original drawing was made on half a sheet of double elephant drawing paper, the temperature scale used being 100 degrees to the inch — a scale abundantly large when a range of temperature of two thousand degrees is to be represented. The part represented on our plate reaches from the absolute zero to 1950, thus extending over 2120 degrees Centigrade so far as our ordinate is concerned.

The genera of elements have been placed at equal distances apart, and arranged in accordance with tension and valence. Conform to the exclusive practice of modern chemical authors we exceptionally place the metalloids first in this plate; we use this rather irrational order to put the subject once in conformity with modern fashion.

At the foot of the plate, all necessary data as to tension and valence have been placed, also our (Greek) symbols of the genera — the names of which are written out in full on the upper part of the ordinates. In the upper left hand corner we have added, for convenience of readers not yet familiar with our Carbon System of the Elements, a tabular view of the same with symbols and atomic weights. We have also in this table arranged the genera beginning with the metalloids, to make this table conform to the plate.

For each element, the fusing point has been marked on the ordinate of the genus to which it belongs. These marks, and the lines connecting the corresponding elements of the different genera, have been marked so as to readily distinguish the elements in each genus according to their order: the *first* or initial element is marked by a small black circle, and these circles are joined by a single rather light line. Tracing this line we start with Fl, then find N, both near the line of absolute zero; then occurs *the discontinuity* — probably the most remarkable in nature — for the fusing point of carbon lies far beyond the upper limit of our plate (certainly above 3000 degrees) and is only indicated by the arrow pointing upwards under the letter C, the symbol of carbon. The fusing point of Bo is also beyond the limit of our plate; Be and Li are represented on the right marginal line of our chart. The fusing point of hydrogen has been added in the left margin of our chart.

The middle part, constituting the *triad* of each genus, has been represented so that it can most readily be traced throughout the system; this is necessary to impress the radical *reversion* exhibited in their order for metals and metalloids, which developed in our study of this subject just concluded.

To mark most strikingly the general succession of the genera we have marked the elements of the *middle member* of each triad by a *full black* circle, and connected these for the genera by a single *heavy line* — which should be traced by the reader as follows: Br, Se, As, Ge, Ga, Zn, Ka.

The *first member* of each triad is marked by an *open circle*, which is connected by a *light single line* from genus to genus. Trace: Cl, S, P, Si, Al, Mg, Na and notice the great *discontinuity* between P and Si, corresponding to the almost infinite discontinuity between N and C.

The *third* or last *member* of each triad is marked by an *open circle* of larger diameter in which a small *central black circle* is shown, and these marks are joined by a *double line*. The reader is requested to trace the third member through the genera, as follows: Io, Te, Sb, Sn, In, Cd, Rb. It will be noted that the discontinuity Sb—Sn is relatively small and *reversed* in direction, being downward.

Finally, the *terminal* member of each genus has been marked by a *large black circle*, and these are joined by a *double heavy line*. Trace: Bi, Pb, Tl, Hg, Cs.

The *mean fusing point* for each genus is marked by an open circle with an oblique cross. For the chloroids, phosphoids and kaloids, all data are observed. For the sulphoids, we have taken —181 as the fusing point of oxygen. For the adamantoids we assumed C 3000 and Si 2000; we also took Bo at 2000, and Mg at 900. It is quite evident that even an apparently large error in these numbers will not affect the resulting mean seriously.

In this way the places of the means have been obtained, as marked: Chloroids, —57; Sulphoids, 150; Phosphoids, 301; Adamantoids, about 1300; Styphoids, about 640; Cadmoids, about 520 and kaloids 82 degrees Centigrade.

The mean fusing point of a genus of chemical elements increases with the numerical value of its valence. It is *highest* for the tetravalent adamantoids, and decreases gradually to each side thereof as the valence falls from four to one, whether the elements be metalloids (to the left) or metals (to the right) of the adamantoids.

This general fact we have insisted on since 1867; it applies also to the boiling points, and together with the electrical contrast has formed the basis of *our natural classification of the chemical elements.*

Passing next to the examination of the different genera in detail, it will be noticed that the two genera of metalloids are strictly what may be termed *normal* in showing a gradual *rise* of their fusing point with the increase of this atomic weight; the order upwards is Fl—Cl—Br—Io and O—S—Se—Te.

The same holds good for the *first four* of the phosphoids: N—P—As—Sb; but the fifth, Bi, shows a most marked inversion, its fusing point being almost midway between that of phosphorus and arsenic, while its atomic weight exceeds that of arsenic by 133.

For the adamantoids, the *first four* elements show this same inversion, while the fifth, Pb, shows a small increase over the fourth, Sn, in the normal direction. Thus the order of fusibility of the adamantoids is entirely reversed as compared to that of the phosphoids, even in the minute detail marked by the fifth member of these genera.

The same inversion is marked:—

first, by the sudden rise from near the absolute zero (N) to about three thousand degrees above (C);

second, by the steep rise of almost 1400 degrees from P to Si;

third, by the moderate rise of about 50 degrees from As to Ge;

fourth, by the fall of about 40 degrees from Sb to Sn, necessary to completely inverse the order in the triads

phosphoids: P—As—Sb upwards;
adamantoids: Si—Ge—Sn downwards.

Fifth, as already stated, the fifth members are inverted in these two genera: from Sb to Bi a fall, hence from Sn to Pb a rise.

This inverted order of the metalloids now remains permanent for the rest of the metallic genera, constituting the most striking contrast between metals and metalloids.

For the styptoids, the fifth member Tl is still above the fourth In as Pb over Sn in the adamantoids; but in the cadmoids and kaloids the entire order is the exact inverse of that of the chloroïds and sulphoids of the metalloids.

The apparent special anomaly of the fifth member is thus restricted to the highest valencies three and four, characterizing the genera styphoids, adamantoids and phosphoids.

We may also express this rather complex condition of things in the following manner: The metals of lowest valence present the metallic character the most completely; so do the metalloids of the lowest valence represent the non-metallic character the best. This is also indicated by their electrical contrast or potential tension being the highest.

Now, neither for the most pronounced metalloids, nor for the most pronounced metals, do we find any inversion of the order for the fifth member of a genus. For these metalloids the fusing point increases without exception as the atomic weight increases; in the same way, the mono- and di-valent metals have a lower fusing point for higher atomic weight, without exception.

But for the tri- and tetra-valent metals, this order is inverted for the last member of each genus; and so it is, in the same way, for the last member of the tri-valent phosphoid, the *brittle* metal, bismuth.

Our diagram, representing the fusing point as function of valence and electrical tension, brings out this fundamental contrast more strongly than any other representation presented.

The signification of this contrast as to the nature or constitution of the chemical elements must be of the highest value; we shall soon inquire into this question.

Before doing so we must put into language a quantitative relation which we have referred to repeatedly as we recognized it from different points of view, and which presents itself in this diagram also in the most forcible and clearest way.

For the *initial member* of the seven genera of elements here considered, the total *range* in fusing point is the greatest; it exceeds three thousand degrees centigrade.

For the *second member* (being the first of a triad) the range is reduced to only about one-half of the above, say 1,500 degrees.

For the *third member* of these genera, being the second member of the corresponding triads, this range is again greatly reduced to but little above half of the just preceding range; the difference Ge—Br being less than 900 degrees.

For the *fourth member* of these genera, or the third member of the triads, the extreme range is Sb—Rb or about 600 degrees.

Finally, for the *fifth member* we have no observations for the chloroids and sulphoids, no fifth member yet having been found; the extreme range is Pb—Hg or about 400 degrees.

The range in fusing point diminishes roughly in a geometrical proportion with the arithmetical increase of the order in the genera. The second is half of the first; the third (900) is greater than half of the second (750), more nearly two-thirds (1000). Going on with this ratio from the third (900) we get 600 which is the fourth, and two thirds hereof is 400 which is the fifth as observed.

It must be understood that no exact ratios are pretended to have been found, but it cannot be denied that the *range* decreases roughly in a geometrical ratio as the order in the genera increases arithmetically from the first to the fifth.

This means that the logarithm of the *temperature range* approximately indicates the *order* in the genus. It is a most general relation between dependent quantities in nature; but it is not possible here to enter further upon this question of detail.

CONCLUSION.

It is impossible to observe the rapidly diminishing range in the fusing points of these chemical elements without recognizing therein a mechanically irresistible argument for the composite nature of the chemical elements.

In passing from the first to the fifth and last known member in each genus of elements, the general chemical and physical characters are preserved, but the *contrast* expressed in the *range* of fusing points decreases in a geometrical ratio. The *first* order of members differ extremely as to oxygen, diamond and lithium; the *fifth* order of members closely resemble one another, for they are Bismuth, Lead, Thallium, Mercury and Cesium.

The atomic weights of the different members of one order differ only about ten units from their mean, which is that of the corresponding adamantoid. Thus Lithium is 7, Fluorine 19, which is respectively 5 below and 7 above carbon 12 in the *first* order. In the *fourth* order, iodine is seven above, cadmium is 6 below the atomic weight 118 of the adamantoid tin. The kaloids in brackets cannot here be compared, as we soon shall learn.

To study the atomic weight of these orders, we therefore can take the atomic weight of the adamantoids as type; for the metals are but little below, while the metalloids are but little above this weight.

The following series represents these data for the adamantoids:

Symbol	C		Si		Ge		Sn		Pb
Atomic Weight	12		28		73		118		207
Increase		16		45		45		89	

Now, 89 is but one unit short of 90, which equals the increase from Si to Sn. Furthermore, 45 is but 3 short of 48, which is 3 times 16, the first increase. We find exactly such laws of combination in organic chemistry, in the so-called radicals; but we shall not enter upon these comparisons here.

We shall merely take notice of the observed *fact*, that the atom of silicon contains 16 units of weight more than the atom of carbon; an atom of germanium contains nearly three times that increase more than silicon; that an atom of tin again contains exactly this amount of matter more than germanium, and that an atom of lead contains double this addition of matter above that of the atom of tin.

In other words, let us reason about *matter as some one identical thing*, *measured by weight only*, but not otherwise different.

Then the atom of carbon for some reason is chemically quadrivalent. In the silicon atom we have this same carbon atom (weight 12) lengthened by exactly 16 units of weight of the same matter, constituting the atom of silicon, which has the same chemical character (quadrivalence, etc.), because *its active head* is the same identical matter constituting the carbon atom, which has somehow picked up the weight 16.

The silicon atom combining with three such particles of 16 — which to permit close combination have each lost *one* so as to leave each a weight of 15 only, constitutes the germanium atom.

An equal increase by 3 such weights of 15 each gives the weight of the tin-atom, always supposing that the original weight 12 continues the quadrivalent head, the same as the carbon atom.

Finally adding double this amount of matter or twice 45 less one unit to permit combination, we have the weight of the lead atom.

As to *how* this matter is joined, there are many possibilities. One of them, apparently the most simple, would be to suppose the second (16) to continue in line with the first (12), making the silicon atom to consist of two links. If the other matter be added all in the same direction, the atom or germanium would consist, first, of the carbon-head, weighing 12, then four links, the first weighing 16, the next three weighing 15 each, total length 5 links, total weight 73.

The next 45 as three links would make the atom of tin consist of *8 links* weighing 118.

Finally 6 more links, aggregating 89 units (instead of the 6 times 15 or 90) would make the atom of lead consist of 14 links weighing 207 units.

Such combinations we have in organic chemistry. The compound methane (marsh gas) has the atomic weight 16, consisting of one carbon 12 and four hydrogen. Being saturated, it does not directly combine; does not act like a chemical element.

But if by any proper chemical treatment *one atom of hydrogen* be *removed*, the residue is termed *the chemical radical methyl;* its atomic weight is 15, its valence is one (namely the place vacated by hydrogen). This radical forms compounds, exactly as do the monovalent elements.

The next organic radical is *ethyl;* it is also monovalent, its atomic weight is 29, containing two links: the active head 14, the next methyl 15.

Then follows propyl of 3 links, butyl of 4 links, up to 36 links. *Each of these radicals has the same monovalent active head; the body increases 14 in weight for each additional link.*

These are organic radicals of

	1	2	5	8	14	links
Weigh,	15	29	71	113	197	
Increase,		14	42	42	84	

It will be noticed that this series of actually well-known organic radicals is astonishingly parallel to the above given series of the adamantoids.

If the series of radicals 1, 2, 3, 8, 14 be combined with hydrogen, we get the corresponding *paraffins* so-called; if with Fl, Cl, Br, Io, Cyanogen (itself a monovalent radical) we obtain the corresponding fluorides, chlorides, bromides, iodides and cyanides. The boiling points of these well-known organic compounds are graphically represented on Plate 5, where the *temperature* is laid off as ordinates or vertically, while the *number of links* is represented by its logarithm as abscissa.

This diagram we copy from its first publication in the transactions, the *Comptes Rendus* (T. 115, p. 177) of the Academy of Sciences of Paris, to which *Berthelot* presented my paper (Note No. 28) on this subject, July 18, 1902.

Now, in this paper the boiling points of all compounds represented on this plate were calculated from the rectilinear structure of the same; the calculated temperatures were found to agree with the temperatures actually observed.

The compounds here specially of interest are those corresponding to the above specified values of n, the number of links; that is, the numbers 1, 2, 5, 8 and 14.

If the links in these organic compounds were not all in one straight line, but arranged in any other way the temperatures calculated from this special position of the links would *not* have agreed with the actually observed boiling points.

The agreement or disagreement of such calculated values thus positively determines whether certain chemical compounds have their constituent carbon links in a straight line or not.

If for example, the arrangement had been this way

		3	6	9	12
1	2	4	7	10	13
		5	8	11	14

(where the numbers represent the consecutive links, each weighing 14), then the calculated boiling points would have been much lower for the higher compounds cohtaining 5, 8 and 14 links. In the above instance, four links would have been treble, and the total length of the atom would have been 6 only instead of 14 measured as before.

Again, it is possible that the three links 3, 4, 5 surrounded link 2, that next 6, 7, 8 also crowded in between these forming a hexagon with 2 as the center. Finally the last six links 9 to 14 might find their places around the preceding hexagon. Thus the total atom of lead would only have a length of 2 links, but in its second contain 13 times the weight of 16 (or rather 15). See Principles, 1874, pp. 181–182.

These are some of the possibilities between which a decision has to be made as to which is the true or at least the most probable arrangement of the total matter of an atom of lead, tin, germanium, silicon as they are built up from an atom of carbon weighing 12 by the material brick or link weighing 15.

It is evident that by methods such as have been referred to in connection with the introduction of *Plate 5* these questions can be definitely disposed of. But this problem of mechanics is more difficult than the one referred to, because the distances between the constituent particles are undoubtedly much smaller than the distances between the element atoms in chemical compounds such as treated of successfully in our above note in the Comptes Rendus. At any rate we cannot in this introductive study enter upon this problem for which the necessary preparation would constitute a full treatment of our mechanics of the three states of aggregation.

A very important point must be considered right here relating to *the apparent selection of the numbers 1, 3, 3, 6* representing the *additions* made to the first or initial element atom. Namely we found the additions as follows: first 16; then 3 times 16; again 3 times 16, and finally 6 times 16 — or a small amount less. In the case of the adamantoids the additions were

16, 3 times 15, 3 times 15, 6 times 15 less one.

This certainly represents a definite mode of *selection*, namely the selection of the factors stated: —

1 . . . . 3 . . . . 3 . . . . 6.

By comparing the series of atomic weights for the other genera, *the same multiples* will be found in every case but that of the kaloids.

Thus for the Styptoids, the values are: —

Symbol	Bo	Al	Ga	In	Tl
At. Weight	11	27	70	114	204
Increase		16	43	44	90
Ratio		1	3	3	6

Here the three last increments are 43, 44 and twice 45.

For the Cadmoids we have

Symbol	Be	Mg	Zn	Cd	Hg
At. Weight	9	24	65.5	112	200
Increase		15	41.5	46.5	88

Where the first is one low, the mean of the next two is exactly 44 and the last is exactly twice this number.

For the Phosphoids we find

Symbol	N	P	As	Sb	Bi
At. Weight	14	31	75	120	208
Increase		17	44	45	88

where P is one high (Mg was one low) and the increments are 44, 45 and twice 44.

For the Sulphoids, the numbers are

Symbol	O	S	Se	Te	?
At. Weight	16	32	79	124	?
Increase		16	47	45	

The mean of the last two is 46 ; twice 46 or 92 added to 124 would give 216 for the unknown fifth member of this genus.

The Chloroids show

Symbol	Fl	Cl	Br	Io	?
At. Weight	19	35.5	80	127	?
Increase		16.5	44.5	47	

The mean of the last two is again very nearly 46 and would indicate an atomic weight of about 219 for the fifth member of this genus still unknown.

In all these cases the increments are very nearly in the ratio

1 3 3 6

The *first* is exactly 16 for the sulphoids, adamantoids and styptoids ; also for the kaloids not yet considered in detail. For the cadmoids it is 15 ; the chloroids show 16.5 and the phosphoids 17.

The *treble increase* of the next intervals amounts to an average of

46	for the	chloroids and sulphoids,
45	" "	adamantoids,
44	" "	phosphoids, cadmoids,
43.5	" "	styptoids,

and the last increase is quite closely double this value.

We understand that the difference between these numbers and three times 16 or 48 indicates the number of bonds that hold these increments to one another around the nucleus already formed — if we may reason from known facts relating to organic radicals and from the structure of inorganic compounds, the so-called ternaries. Programme 1867, p. 16; Principles 1874, p. 181.

Turning finally to the Kaloids we find

Symbol	Li	Na	Ka	Rb	Cs
At. Weight	7	23	39	86	133
Increase		16	16	47	47
Ratio		1	1	3	3

Here we evidently have *one more single link* added to the first element atom, Lithium. The binding is the least firm, the treble link lacking only one in the uncombined 3 times 16 or 48.

It appears therefore that Potassium is related to Sodium exactly as the latter is related to Lithium — the additions being made in a straight line, forming a prismatic body. Then the increase goes on by the treble link as in the other genera.

A *sixth member* must therefore be supposed to exist in this genus of elements. Its atomic weight would be twice 47, that is 94 in excess of the last named, cesium 133; this gives 227 for the sixth kaloid. No such element is known at present. But the next group corresponding to the kaloids and built exactly on the same plan is the following: —

Symbol	Be	Mg	Ca	Sr	Ba
At. Weight	9	24	40	88	137
Increase		15	16	48	49
Ratio		1	1	3	3

The next higher member of this genus — embracing the old triad of the Calcoids, Ca, Sr, Ba — would be say twice 48 or 96 above 137, that is 233. It would have to prove its calcoid character by the insolubility of its sulphate, by its flame coloration, spectrum, and the like.

Seven years ago no such element was known; nor is it quite certain that such an element has been discovered to-day, for it has not yet been produced in the free state. But the chloride, bromide, and sulphate of what is called *radium* accord excellently with this supposed sixth member of the genus considered, or a fourth member of the calcoids. The atomic weight determinations made are stated to give 225; but this may be low, since it is admitted that the compound operated upon did still contain some barium. The examination of the spectrum of radium has convinced *Runge* and *Precht* that this value is too low; they calculate 258 from their spectroscopic measurements.*

It is quite generally accepted by chemists to-day, that this much renowned radium is a chemical element and forms a fourth member to the calcoid-triad. In case that view is proved true, it will no doubt also follow that its atomic weight is nearer the figure 233 we find, than the figure 225 determined by the discoverers of this substance, the Curies, of Paris.

Many other chemical elements are related to these two groups, the higher kaloids and the calcoids, both in their chemical character and in their atomic weights; they are commonly known as the *metals of the rare earths*. Their chemical investigation is exceedingly difficult and will require very much work to produce satisfactory results.

We may now finally examine the atomic weights of the group of elements named *palladoids* and placed near the cuproids when studying the fusing points.

Symbols	Co	Pa	Pt
At. Weights	59	106	194
Increase		47	88
Ratio		1	2

For the cuproids we have

Symbol	Cu	Ag	Au
At. Weight	63.5	108	197
Increase		44.5	89
Ratio		1	2

These groups correspond to the last three members of the gen-

---

* Berlin, Sitzungsberichte, 1904, pp. 423–425.

era of five elements first considered, but at least the palladoids cannot possibly be connected in any way with elements of low atomic weight. They must be looked upon as forming a system of elements by themselves.

The most common typical metal of this system is *iron*, and we have therefore called this entire division the *iron system* of chemical elements.

We may now graphically represent all known elements in one diagram according to their fusing point and atomic weights. See Plate *6*.

We place the most electropositive *kaloids* at the top, and the most electronegative *chloroids* at the bottom, with the *iron system* in the middle.

The *ordinate* in each of the three great groups so resulting is the *valence*, running from 1 to 4 (adamantoids) and down again to one.

The *abscissa* represents the *atomic weight observed*, the groups related to carbon and silicon are necessarily common to the Kaloid Division at the top and the chloroid division at the bottom.

From these the other elements may be supposed to have grown out under the *two* methods already brought to light, characterizing the *Kaloidal* or electropositive division and the *chloroidal* or electronegative division.

In the Kaloidal Division the first increase of 16 is repeated, as in the Kaloids; then follows the *treble* interval (48 or less) twice, and finally the *double-treble* (96 or less). *The metals of the rare earths* constitute the bulk of this division of the elements.

In the *chloroidal division the first increase of 16 is not repeated*, but immediately followed by twice the *treble* interval and closed by once the *double treble.* The most *common elements*, all metalloids and the heavy fusible metals, belong to this division.

The densest and most difficulty fusible metals, forming the *iron system*, are placed between these two divisions, comprising the least fusible and least volatile of all elements. In this division we can detect no *simple and constant valence* rule; the *valence is rather indefinite, variable*. As to the electric character, we notice a most remarkable peculiarity in the iron system. The lower atomic weight here is associated with a pronounced electronegative character (Cr, Mo, Wo) while the higher atomic weights are less so and therefore relatively electropositive.

In both the other divisions, namely the kaloidal at the top and the chloroidal at the bottom, the electropositive character is peculiar to the elements of lower atomic weight.

The *small Greek symbols* marked at the beginning of the Kaloidal Division may be used to designate *the first two or three members only* of each genus; the corresponding names are, by valence:

1, lithoids; 2, berylloids; 3, boroids.

From valence 4 to 1 down, the same symbols (only lower case) being used as before, the names remains the same.

It will be recognized, that this system makes the existence of elements with atomic weights ranging about 182 extremely improbable in the kaloidal system or in any other. Only two elements are located here, namely, Ytterbium and Tautalium. Very careful research on these two elements is urgently called for to determine whether for the longer core the additions continue without a break in multiples of the *treble* 3 times 16.

Now, having obtained an idea of *the probable genesis of the chemical elements from one single material substance*, which we have called *pantogen* we may, for a moment, revert to the question we started with, namely the decrease of the range of the fusing point in a geometrical ratio, as we pass from the first to the last of the five members of each genus of elements.

The *first* elements of the genera, consisting of but *one mass of pan-atoms*, running in weight from 7 in lithium to 19 in fluorine (the weight of a hydrogen atom being taken as unit) is first *lengthened* by one weight of 16 in the chloroidal division, then by *treble* this weight *twice* in succession, finally by as much again (a double *treble*).

The *increments* or additions are

1 .... 3 .... 3 .... 6 times 16.

The *total additions to the first member* therefore are 1, 4, 7, 13, times 16.

In the *kaloidal division* we find the addition of 16 to the original atom *repeated* a second time; that is, the *increments* are

1 . . . . 1 . . . 3 . . . . 3 . . . 6,

and the *additions* made to the first therefore are

1, 2, 5, 8, 14 times 16.

As now the *first* element of each genus averages the weight of a carbon atom or 12, we notice that the *additions are rapidly increasing* and therefore must rapidly blot out the striking *physical* properties of the *first* member while the *chemical character* remains largely unchanged, residing exclusively in the active head or first nucleus of the atoms of each genus.

This is precisely what we see so strikingly represented in our diagram Plate *10*, where the line of the *fifth members* Bi—Pb—Tl—Hg—Cs is generalized in the curve of alternating larger and smaller black circles shows the general trend: from the atomicity zero rising gradually with the valence to the tetravalent lead, and as gradually descending with the lowering valence to the zero on the right.

This curve, which resembles the familiar probability curve, represents the final extinction of the striking physical contrast between the metalloids and metals of the *first* order: Fl—O—N—C—Bo—Be—Li, by rapidly increasing equal masses. The first contrast has also been typically represented by the curve of tangents.

Origin of the Ratio 1 : 3 : 3 : 6.

We have compared the chemical elements to organic radicals, and found quite a resemblance between them. In both we recognize the chemically active *head*, which marks its valence; and in both we have a more or less considerable *body* not possessing active chemical properties, but greatly modifying the *physical* properties of the element or radical and of their compounds. This comparison will now, we trust, be much better understood than it was at the time we first presented the same.

But we also now can more thoroughly appreciate at least *one* striking difference between the series of organic radicals and the series of elements which contribute a genus.

In the series of monovalent organic radicals beginning with methyl and increasing in its body by the link weighing 14 we know every member corresponding to every natural member from 1 to over 30. But in the series of elements comprising the chloroids we meet only the *additions* corresponding to the members 1, 3, 3 and 6 giving the totals 1, 4, 7, 13. Or if we prefer to count in the first element (here fluorine) the *aggregates* or totals are (approximately) represented by the series of numbers 1, 2, 5, 8, 14. In this series are missing the numbers 3, 4; 6, 7; 9, 10, 11, 12, 13 or *nine* in all. Of all 14 numbers, only *five* are found, while nine are absent.

At first sight, this appears very strange; it is one of the simplest and most primitive cases (in time) of *aggregation*, akin to *crystallization*. A nucleus — the atom of second element in the chloroid (or third element in the Kaloid) combining with more of the pantagen groupings (of weight 16 or a little less, as we have found) will complete an equilateral triangle with three, then fill the space, completely forming a hexagon; and if to grow still further, it will require again six such bodies.

In the middle of the right side of Plate *10* we have shown this by construction, assuming that these weights 16 form equal cylindrical bodies. The different marking of the centers has simply been done to distinguish the order of combination.

In the growth of the element-atom we seem to see first that little body which will remain the chemical *head* for the entire genus, fixing the valence thereof; f. Ex. Fluorine. This atom axially continuing to grow takes up the link 16, forming the atom of chlorine. Three such links equally joining in an equilateral triangle around this nucleus form the atom of bromine. Another step completes the hexagon of the iodine atom. The final form, having another six such links constituting an outer hexagon, forms the highest chloroid element, not yet discovered by the chemist.

The question of contact between these portions is involved in the lack of the full 16 of these links; we cannot consider that subject at this point.

TWO GREAT THINKERS.

On the whole it does not seem to us that *the Pythagoreans and Plato* were so very foolish in their ideas about the nature of things, holding that the essence of matter is expressible in numbers or geometrical forms. We certainly have here come face to face with one of the most fundamental facts of nature expressed by the form of the equilateral triangle direct, inverted and reduplicated. If in this brief inductive exposition we could find room for the consideration of the crystal form of the elements and their compounds, we would again meet this same geometrical form — and once more find reason to admire the profundity of the great thinkers of old — Pythagoras and Plato.

As an expression of our admiration for these great investigators who twenty-five centuries ago have so deeply looked into the things which have fascinated and determined our incessant labors for half a century, we have copied (Plate 10, under title) the inscription over the entrance to the school of Plato: " Let no one enter here who does not know geometry," and have also chemically modified the old symbol of the two symmetrical equilateral triangles — which will readily be recognized as geometrically identical with the transverse structure of the chemical element-atoms shown on the opposite side of Plate 10.

And if, with Solomon, we " look upon the lilies of the fields," we find this same symbol constructed in wondrous beauty in each flower of a day; if we dig the crystal gem from the depths below, we again behold the same symbol in the adamantine luster of its geometrically exact facets.

And if perchance we should stray into or at least with eyes open should pass by one of the grand structures erected in the " dark ages " by men animated by faith in the unseen truths of God's World — we again would behold that triune symbol wrought in stones to let the light of heaven into the temple.

THE SYSTEM OF ATOMIC WEIGHTS.

The systematic classification of the chemical elements based upon their fusing point and valence is of so fundamental importance that we ought to confirm the result just obtained by another method of induction, if possible.

We have published such a method in our True Atomic Weights in 1894; we shall repeat the outline here, using the same diagrams (Plate IV and V of that work here reprinted, Plates 7 and 8.

We suppose the atomic weight and valence of each element to be known; we also know their general relation, their *genera*. Nothing more.

For each natural group or genus of elements, we arrange the individual elements in the order of their atomic weight. The sulphoids f. Ex: O, S, Se, Te, ... In this order we call them the *first* (Oxygen), *second* (Sulphur), *third* (Selenicum), *fourth* (Tellurian).

With these data at hand and which data can be taken from almost any modern work on chemistry, we graphically determine the place (point) of each element on a large sheet of drawing paper, using the *order number* of the element as abscissa, and the *atomic weight* as ordinate; the latter we count downwards for convenience.

In this manner the *points* on Plate 7 have been accurately determined, this plate being a reduction by photography of our large, most carefully constructed drawing. The chemical symbols is entered near each point for the identification of the elements referred to.

We notice first, that the kaloids form the extreme limit above and to the right, while the chloroids form the limit below and to the left. All the other elements fall between these two extremes. The upper right empty field we might mark: electropositive; the lower left field: electronegative.

Now, in connecting the date representing the individual elements of a genus by straight lines we find *first* no intersections, no tangle of lines, but a *system of practically parallel groups of lines*.

This geometrical fact proves that *the chemical elements are built or constructed on essentially one and the same plan*.

We next discover that the points marking the middle three elements (the old triad) of every genus form a straight line, very nearly or exactly so. See Cl—Br—Io of the chloroids, Ka—

Rb—Cs of the Kaloids. It will be recognized that these lines Cl—Io, Ka—Cs and all the others, are practically parallel to the line B—C which has its terminal abscissae at 2 and 4 while its terminal ordinates are 32 and 128, that is *two* times 16 and *eight* times 16. The *rise* in atomic weight corresponding to the *double* interval from 2 to 4 is therefore *six* times 16, or amounts to three times 16 for *each* of the *single* intervals from 2 to 3 and from 3 to 4.

The *initial line* joining the first two elements in each genus is seen to be practically parallel to the line A—B which from the order zero to two falls 32 divisions, or has a *fall of 16* per order unit. Compare lines Fl—Cl and Li—Na, the extremes, and notice their parallelism with line A—B.

The *final* lines, joining the last member of the triad with the last member of any genus (see Sn—Pb) is practically parallel to the line C—D which in *one* interval of order (4 to 5) sinks from C at 128 to D at 224, a distance of 96, which is 6 times 16.

In the plate only six genera-lines have been drawn out, they are seen to be parallel to the broken line A B C D just characterized.

Accordingly this diagram proves geometrically or graphically that in every genus of elements, the atomic weight rises in the initiatory part *once* 16 units for each order number, in the *middle or triad-part three* times 16 untits for each order number, while in the *terminal part* it rises *six times* 16 units for each order number.

Here we have graphically (or geometrically) demonstrated the great general fact that *in every genus of chemical elements, the consecutive individual elements result from the first by an increase in atomic weight of 1 : 3 : 3 : 6 times the number 16*, as near as the eye can detect on even a large scale drawing.

In order more readily to keep track of the elements in each order number, the points are alternately marked by *open* (valence an odd number) and *full black* circles (valence an even number). This permits the more ready identification of the elements on this chart.

We next see that there are *three distinct groups of chemical elements*, namely: —

I. *Kaloidal elements*, in which each genus has *two* elements built up by the addition of *once* 16 thus forming an initial triad, as Li—Na—Ka, marked or characterized by *three points* (three elements), forming but *one straight* line;

II. *Chloroidal elements*, in which each genus has but *one* element built up by the addition of *once* 16; see the line of chloroids, not continuing a straight line from Fl to Br, but only to Cl; and

III. The *ferroid elements* which do not start (are not connected with) the initial elements under A B, but *fill the space between the two preceding groups on exactly the same plan*, namely developing elements parallel to the lines BC and CD (triad and terminal). Trace the line of sideroids: Fe—Ru—Ir, and its light (kaloidal) branch Sa—Ur.

A *fourth division* is indicated as possible, starting about 172; but thus far there seems to be no indication of the actual existence of such elements.

If we now wish to present a view of the entire system of chemical elements, by continuous straight lines (unfolding A—B—C—D) we must place the kaloidal elements first, the ferroidal next and the chloroidal elements last, as we have done in our Plate 6.

If we wish to show the mode of accretion or growth of the members of the several genera of elements in the plainest and simplest manner, we must restrict ourselves to the representation of a *typical case* for each of these three great divisions of the chemical elements.

As such typical cases we take the *central* members of each division, shown on our Plate 8, where the *carbon* and *iron* systems are represented in outline.

The initiary triad C—Si—Ti shows a visible deviation in the last member. The kaloidal or *light* branch is Ti—Zr—Ce, while the chloroidal or *heavy* branch is the triad Si—Ge—Sn and the terminal Pb. The members of the iron group have just been specified above.

As a matter of fact, we shall soon learn that the kaloidal branch is made up of elements of less specific gravity than the chloroidal branch. We therefore conveniently may distinguish these branches by the simple words of *light* and *heavy* marked on Plate 8 to the left, where the *mere increase* in the three great divisions of elements is shown, starting with carbon and with iron.

No initiary gives the iron group; *one* initiary element gives the *heavy branch* of the carbon system; while *two* initiary elements lead to the *light branch* of the carbon system.

We may also call attention to the cross-section marks: 3, 6 and 12 circles around the central circle representing the *first* member of the triad.

The diagrams in the upper right hand of this chart cannot be considered in this inductive exposition.

It is hoped that all readers are sufficiently familiar with graphic representations of numerical relations, that is geometric reasoning, to have obtained from these two plates a clearer insight in the constitution of the chemical elements that is thus geometrically and therefore mathematically demonstrated.

The same unity or plan or structure was obtained in the preceding section, but less directly, from the study of the fusing points in connection with the atomic weights.

In concluding this topic it may be advisable to refer to one special point about which a misunderstanding may creep in and do considerable harm. I refer to the *differences* between the apparently required theoretical value and the value furnished by experience, or experiment.

Now, as to the first, it must be understood that a full development of a theoretical principle often shows secondary minor variations the cause of which at first remains hidden. Thus, in the majority of cases, the *first* increase of atomic weight is 16 exactly. Yet for Mg it is 15 only, and for P it is 17. In these cases evidently Be is too high (9) making the interval one low, while for P the atomic weight is one high, making the interval also one high. The real question here is: why is Be 9 instead of 8, and why is P 31 instead of 30.

The *first* of these questions is readily answered, for a general rule is plainly visible covering this case. While we cannot enter upon details here, the thoughtful reader will notice that we find a regular rise by two from carbon to oxygen (three elements) broken at Fl which last negative is one high. From the first positive Li we find a regular, constant interval of two for three consecutive elements; this makes the interval Bo—C only one. Thus, there is perfect order even in the apparent discrepancy; it could be mathematically expressed by a term of one dependent on the valence.

This hint may be sufficient at this time.

Again it must also be borne in mind that the numerical data furnished by experiment or observation are not necessarily exact, but may be in error themselves.

The main thing to be considered in this connection is the fact that the theoretical requirements as now understood and as here represented *throughout the entire field of the better known chemical elements* agree very closely with the data now known as the result of experimental determinations of atomic weights, boiling points, fusing points, specific gravity and the valence and electrical character of the elements.

The total number of Chemical Elements and the Cosmochemical Flower.

It may be of interest to try to answer the question: how many chemical elements exist or are possible according to our system.

The general view of our system shows that the general structure is the same for each valence. There must then be *eight* such systems as are represented for the valence four on plate 8.

We distinguish two systems, that of carbon and of iron. For the first we have the initial triad or 3 elements (C, Si, Ti) with the two branches; the *heavy* starting from Si and comprising the triad Si—Ge—Sn and the terminal Pb; and the *light* branch starting from Ti, comprising the triad Ti—Zr—Ce and also (now admitted) a terminal of the order radium and thorium.

Thus we recognize the existence of *nine* distinct chemical elements in the carbon system for every valence.

This makes nine times eight or 72 chemical elements, to which must be added the internal H and He giving *74 elements belonging to the complete carbon system.*

In the *iron system* the valence is not fixed, but we know representatives for at least six of the eight valence groups. For some of these we know the entire number represented on plate 8, namely the triad with one terminal to each of the last, also distinguished as light and heavy laterals. This makes *five* elements for each valence or *forty* in all.

Accordingly we must say that *the entire number of chemical elements* that have formed from the one primary matter *pantogen amounts to 114.*

The total number of chemical elements actually known to-day is not more than two thirds of this number. Surely, the young chemist of to-day need not fear that the field of work is exhausted and that there remains nothing for him to do.

We must remember that we have pointed out the possible existence of a still higher system than our iron system. How complex that system may possibly be we dare not dream of; we have enough work to do searching for the host of elements indicated.

Having obtained an estimate of the total number of chemical elements we would like to see them all equally well represented to the eye, each one standing out as plainly as any other element. Such is not the case in the graphic representations of the chemical elements thus far used. In all our previous diagrams the dimensions have been relatively narrow so far as the valence is concerned, crowding the element-genera closely into parallel lines. Only the diagram *Plate 10* is free from this objection, showing the genera equally well as to valence, but it covers the heavy members of the carbon system only.

In *Plate 11* we have produced such a *view of the entire system of chemical elements*, showing all groups and divisions equally well.

The center point represents pantogen, the prime matter from which all elements are supposed to have been formed. From that point grow out *eight leave-like* systems of points, all alike, and each one representing one valence: the lowest zero, upwards; the highest four, downwards, and therefore representing the nullovalent *Argonoids* upwards, the quadrivalent *Adamantoids* downwards.

Between these two vertical leaves we see both to the right (electropositive) and to the left (electronegative) three leaves representing elements of valence one, two, three in numerical order.

Thus, the full blown *World-Flower* shows the following eight leaves: Upwards, the nullovalent *Argonoids;* to the right the electropositive elements, first the monovalent *Kaloids*, next the divalent *Cadmoids*, third, the trivalent *Styptoids*. The next leaf, directed downwards, represents the quadrivalent *Adamantoids*, introducing the electronegative elements to the left: first, the trivalent *phosphoids*, next the divalent *sulphoids*, then the monovalent *chloroids* which again are succeeded by the nullovalent Argonoids.

It is not necessary to dwell upon the orderly succession of physical properties, such as fusing point and the like; the reader will readily recognize the completeness of this graphic representation.

Each single leaf consists of two distinct parts — the carbon system and its iron system of this group. In a more complete representation in space we might represent it by two leaves, as every flower consists of a calix and a corolla; the latter would naturally represent the higher and more volatile elements of the carbon system, while the former would call to mind the iron system.

In each of these the main line of *heavy* elements is marked by the *full black* circles, while the open circles represent the correlated *light* branch of elements. In the latter, the *radium* (or thorium) *link* has not been drawn; it would reach out the furthest, for the circles representing the elements are drawn at distances from the center (pantogen) proportional to their atomic weights

In order not to diminish the main graphic value of this symbolic and yet strictly geometrical diagram drawn to scale, we have written only the chemical symbol of the most common (second) member in the carbon system, and of the most familiar *first* member of the iron system. By means of the details given before, any reader will *readily identify the place of every known element* at the proper point in this diagram. He will then also find the numerous elements which we cannot doubt do exist, but which have not yet been discovered. — See the corresponding statement, p. 5, close of paragraph 2 of our Programme of 1867.

If we were inclined to make a show of profound wisdom at a very small outlay of work, we might enlarge upon the *properties* of these unknown elements. A mere nothing as compared to this has made a very ordinary chemist most famous, and then he merely hastily generalized what he had read and seen represented in my Programme der Atommechanik, published 1867. See, also, True Atomic Weights, 1894, pp. 239–255.

As the construction of this symbolic flower of the chemical elements shows, the atomic weight *increases* from right to left, in each spire, facing the flower, so far as the *carbon system* or the corolla is concerned.

Since the calix representing the iron system shows the same electrical character, the atomic weights therein *diminish* from right to left.

This most remarkable feature was not only represented but accentuated in the corresponding diagram of our *Programme* of 1867, which diagram has been reproduced on p. 215 of our *True Atomic Weights* in 1894, and on page 396 of our *General Chemistry* in 1897, where on p. 397 the *cosmochemical flower*, Plate 11, was first published.

By spending a few hours study on this flower diagram, using all the data of the preceding parts of this little introduction to theoretical chemistry, many known relations of the elements will appear in a clearer light and many new relations will spring into view.

FREQUENCY IN DISTRIBUTION OF THE ELEMENTS.

This may also be the best place to consider the interesting question of the *frequency* or relative amount of the different chemical elements and their *distribution* or location in nature.

As to *frequency* it is evident, that an element atom will form so much the more frequently as it is simpler in structure, as it requires a less number of conditions to permit its formation. Therefore we must hold that in every genus *the frequency is greatest for the lowest orders*.

By the same rule we must hold that the *light* elements of the carbon system must be less frequent than the *heavy* elements.

This has long been recognized in the common term of the *rare earths* as contrasting with the ordinary ones of the heavy branch.

Thus all the members of the iron system may also be considered less numerous than those of the carbon system.

But since the relatively greater frequence of the atoms of the less complex elements in weight is possibly fully compensated for by the individually greater weight of the more complex atoms, *there may in all nature not be any marked difference in the total weight of the various chemical elements.*[*]

In a *cosmical sense*, a given weight of gold may be as common as an equal weight of iron, and a given weight of silver may be as common as an equal weight of tin.

At the same time, there must necessarily obtain a great variation in the frequency of the chemical elements *at any given place* in the world. To man, living on the surface of this terraqueous globe, gold is rare, iron is common, and silicon, magnesium, aluminum, and iron form the bulk of the rocks of the outer crust of the earth.

Supposing the total weight of the different elements to be not very different in the world, it is readily understood that during the countless ages that have elapsed since the elements formed from the prime-matter (pantagent) they have responded to all natural agencies in virtue of their individual properties.

Hence to-day the lightest elements prevail in the outermost parts of the earth and other commercial bodies, especially in their atmospheres. Even in our own atmosphere we have shown[†] such a partial separation: the lower strata only contain the oxygen and nitrogen; higher up first the oxygen disappears while hydrogen becomes more frequent, leading to an outermost envelope of hydrogen and helium.

The gradual change of the main rocks of the outer crust of the earth has been studied much, also in comparison with the two classes of meteorites, stones and irons, which are properly considered fragments of extra terrestial bodies. This question has

---

[*] The exact relation here involved has been studied by me many years ago, also in reference to meteorites; a special publication hereon will soon be issued.

[†] Comptes Rendus, 1900, August.

engaged my attention frequently, and results obtained have been stated in connection with my earlier publications on meteorites. As I am now ready for a special publication on this subject, this mere mention may suffice in this place.

But it is not only the testimony of the rocks and veins accessible to us, nor the parallel evidence of the meteorites that is at our disposal; we possess most absolute astronomical knowledge of the density of the interior part of the earth, according to which the central portions of the earth must possess a specific gravity of at least 16, while the mean density of the earth is only about 5 and the outer rocky crust only about two and a half. See publications Plana of 1853.

It is easy to demonstrate from these data, and from the known density of the elements and their compounds, that *the central core of the earth must consist of the heaviest of the known elements as such or in the state of alloys.*

It is not even the fourth member — from silver to tin — but the *fifth* member, from gold to mercury, that can furnish the only known elements to bring about an average density of at least sixteen for the inner core of our globe.

While near the surface, gold is rare, in the depths of this globe gold and the like elements become gradually more abundant, indubitably forming the main part of the innermost core of this earth.

The "statistical data" furnished from certain scientific bureaux (where a lot of "scientists' are to be kept mechanically doing something easy) obtained by collating actual analyses of rocks and minerals made by the hundred in other divisions of the same bureaux, cannot teach anything whatever as to the relative frequence of the chemical elements.

The Atomic Volume of the Elements.

We have now completed a simple demonstration of the composite nature of the chemical elements, so far as it is possible in a popular form.

It has been shown that the most important physical properties of the different elements indicate the definite structure of these elements described at some length.

For detail we have in a general way referred to our publications on this great subject, enumerated at the opening of this work. We have not made many specific references, because that would be of no value to the general reader, while the scientist will have to make himself familiar with as many of these publications as possible.

It has been specially stated that our publications on the mechanics of the three states of aggregation are of special importance; a new, more complete work on this topic has been in preparation for a number of years, and will, it is hoped, be published within a year from this time — in which case it will have been under our hands for exactly half a century. The almost forty Notes published in the Comptes Rendus treat mainly of this subject, and form a volume of 140 pages quarto.

Supposing now, that what has been shown here as to the structure of the atoms of the chemical elements is, in the main, conclusive, it would be very desirable to *confirm* these results by another method of demonstration, dependent upon another fundamental property than the fusing point mainly used thus far.

Such a property we have in the *atomic volume* of the chemical elements, which expresses the relation of the atomic weight to the specific gravity of the elements.

It will be remembered that we temporarily discontinued the consideration of the specific gravity of the elements, replacing that *physical* property by the *chemical* determination of the atomic weight.

Having now studied the relations of fusing and boiling point to the atomic weight, we may also consider *the precise relations of the specific gravity to the atomic weight.*

We shall, in the course of this new study, find *a most conclusive confirmation* of the results obtained by the study of the fusing point.

The *specific gravity*, G, divided into the *atomic weight*, a, gives as quotient the so-called *atomic volume*, V; for G being the weight in grammes of one cubic centimeter of the element, the quotient V evidently represents the number of cubic centimeters of space occupied by *a*-grammes of the element, that is, by as many grammes as the *number a* indicates.

For example, the atomic weight of the compound *water* is 18; its specific gravity is 1; the quotient V is therefore 18, and indicates that one gramme-atom of water (18 grammes) occupies a volume of 18 cubic centimeters; that is, the atomic volume of water is 18.

Again, the specific gravity of liquid hydrogen (at its boiling point) is 0.07; its atomic weight is unity, 1; hence its atomic volume is 14.3, which means that one gramme of liquid hydrogen fills a space equal to 14.3 cubic centimeters.

Or still another important case: the specific gravity of the diamond is 3.50 to 3.55; its atomic weight is 12; hence its atomic volume is 3.43 to 3.38, which we put down as 3.4, and means that 12 grammes of diamond occupy exactly 3.4 cubic centimeters.

One more example may be desirable to obtain a clear insight into the determination and significance of the *atomic volume*. The specific gravity of metallic potassium has been found to be 0.865 at 15 degrees; its atomic weight is 39; hence its atomic volume is 45.1. This expresses the fact that 39 grammes of potassium (Kalium) occupy 45.1 cubic centimeters of space.

We trust it is now fully understood what is meant by the *number* expressing the atomic volume of any chemical compound or element. It is also apparent that it expresses the experimentally determined specific gravity in relation to the equally as well determined experimental fact of the atomic weight of the same compound or element, so that we have *in the atomic volume a numerical quantity determined empirically* by physical and chemical experiments combined.

We may therefore examine this *empirical* atomic volume and study its relations to any other experimentally ascertained fact; as such we will here again select the atomic weight, which likewise is an experimentally determined quantity.

In plate 9 we have the result of such a graphic comparison of atomic volume to atomic weight. We have taken as abscissae (horizontals) the atomic weights, and as ordinates (verticals) the atomic volume; the point of intersection of these two lines (equal to the numbers a and V according to the scale marked on the diagram) marks the *place* or *point* of the element considered.

To find the place or point of the diamond, we set off its atomic weight 12, according to scale marked on the base of the diagram, to the right; erect a perpendicular and cut off hereof the length 3.4 units of the scale of volumes marked on the sides of the diagram; the point thus determined represents the diamond. We have marked it by a square to indicate the quadrivalence of carbon.

Since carbon also occurs lighter as graphite, we also find the atomic volume thereof above that of the diamond. In the same way the point (full back circle) marked Ka is determined by erecting a perpendicular to the base at its point 39 (the atomic weight of Ka) and cutting off the length 45.1 (the atomic volume of Ka.)*

In this manner every point marked on this chart has been found by the experimental determination of the atomic weight and atomic volume of the element indicated by the *chemical symbol* near the point. The points themselves have been marked black for the metals, open for the metalloids, and indicate by their size and shape the *valence* of the element, as shown near the right hand lower corner of the chart.

Finally, *the points marking elements of any one genus have been joined by lines*, and these lines are designated by the *Greek symbol* of this genus.

All the data thus graphically (geometrically) represented in their numerical values on this chart *are facts observed*, determined in the course of many years by the physicists and chemists of many lands.

These facts being represented geometrically, we can study them by carefully looking at them with our eyes; this is the great advantage of our method of investigation. Let us examine this chart and let us state in words what we see.

---

* We intended to insert both the full plate (small scale) and the *lower half* of the plate *enlarged,* but have concluded to print the latter only, which leaves the elements Ka, Rb, Cs (and these only) beyond the limits of our plate.

The most striking features of this chart are the following three: —

I. The line of atomic volume of the *Kaloids* rises the most abruptly and is throughout the highest of all.

II. The line of atomic volume of the *Palladoids and Cuproids* is the lowest and rises the slowest of all.

III. The line of atomic volume of the *Chloroids* is almost midway between these two extremes.

This is exactly the same grouping as we have found for the fusing point, showing a like relationship of constitution as proved by the fusing point lines.

Reading next the *Greek symbols* of the genera upward at the left margin we find the following order (adding the *valence* in parenthesis): —

Palladoids, Cuproids, Cadmoids (2) Styptoids (3), Adamantoids (4), Phosphoids (3), Sulphoids (2), Chloroids (1). This is *exactly* the order in which the genera occurred before (for fusing point) and in which we have placed them on our general charts. Compare Plates 6, 7, 9 and others.

The place of the cuproids here represents heavy monovalent elements; but only silver is really monovalent, and it may be considered that for these very dense, most strongly metallic elements, the peculiarity of the central iron group in the next lines below is already marked by the absence of a definite, constant valence of the cuproids.

As to the *direction* of the last part of these lines, connecting the last two elements of these genera, the following facts are apparent (omitting of course these lines for the sulphoids and chloroids because the fifth members thereof have not yet been discovered):—

These lines of atomic volume *are nearly parallel* and but very slightly rising, showing almost equality of atomic volume for the last two members of each genus here represented. The lines for the Sideroids (Ru—Ir), Palladoids (Pd—Pt) and Cuproids (Ag—Au) are not only parallel, but also horizontal, forming an angle of zero degrees (with the base of the plate). For all these elements, the atomic volume of the last two members of each genus specified are really equal, notwithstanding their enormous difference in atomic weight.

The corresponding lines for the Cadmoids (Cd—Hg) and Styptoids (In—Tl) are also parallel, but rise slightly, forming an angle of only 6 degrees with the horizontal base of the plate, which corresponds to a rise of about one unit on the atomic volume for a change of hundred units in the atomic weight.

The corresponding adamantoids (Sn—Pb) rise a little faster, their connecting line being inclined to the horizontal base under an angle of about 7 degrees, while the trivalent relatively negative phosphoids (Sb—Bi) form a straight line which rises under about 10 degrees.

The general results just observed concerning the near equality of the atomic volume of the last two members of the various genera specified confirms anew the former observation (for fusing point) that in the higher members of all genera the physical properties come near together, only the chemical character (valence) remaining distinct.

This confirms the former conclusion, that *the higher members must result from the lower ones by the addition of matter of the same kind* (*pantogen*).

Let us now inspect the initial part of the lines representing the atomic volume of the different genera.

Here we may first take note of the very striking fact that the *nullovalent elements* (Argonoids) are found almost exactly midways between the monovalent electropositive kaloids and the monovalent electronegative chloroids. There can be no doubt about the position of this nullovalent group of elements; it stands where our formula published in 1874 placed it, and where a group is required between the monovalent electronegative and positive elements. See our diagram Plate 11 and notice the numerical details and algebraic formula in the upper right hand corner of Plate 10.

Looking a little closer into this left quarter of our plate we find the three elemental gases H, O and N quite close together, and possessing a rather large atomic volume (about 15), almost equal to that of water (18), while the solid, most difficultly fusible and least volatile elements C and Bo also are near each other, but very much below the three gaseous elements. The monovalent gas Fl, when liquefied, has a larger atomic volume than the other three liquefied gases.

Here we have a repetition of *the most striking discontinuity* already found before for the fusing (and boiling) points of these elements of the first order. We also here merely take notice of *this fact* now strongly re-enforced; for a solution, we must look to a later chapter.

We must here notice that the two metallic elements, lithium and beryllium, are placed between the gaseous and solid metalloids.

Having found the location of the initial element of each genus, we may next trace the line of atomic volume of the *initial triads:* Li—Na—Ka; Be—Mg—Ca; Bo—Al—Sc; C—Si—Ti for the electropositive elements from monovalent to quadrivalent in chemical character.

We see at a glance that *these triad lines of atomic volume are straight lines* and the middle element marks nearly the middle of these lines, which of course signifies that the *increase* of atomic volume from the first to the second is about the same as the increase from the second to the third element.

Since the atomic weight increases in these cases by the same (or very nearly the same) amount 16, we may also express the fact of the equal increase in the corresponding atomic volume by saying that *for all these genera the connective addition of 16 to the atomic weight produces an equal increase in the atomic volume in* each separate genus.

The *amount* of this increase is by far the greatest for the monovalent kaloids; diminishes greatly as the valence rises to two; then more slowly, being smallest for the tetravalent genus. This roughly corresponds to the fractions:

$$\frac{1}{1} \qquad \frac{1}{2} \qquad \frac{1}{3} \qquad \frac{1}{4}$$

We cannot here develop the reason of the *duplication of the increase* in the first two members, nor of the *reduction in absolute amount* with increasing valence; for the purpose of *induction, the* *fact is the main thing* we can bring out in this short popular exposition.

But we may be permitted to refer to our work on atomic volume in our *Programme* (1867), our second *Contribution* (1868), our *Note* X (Acad. Science, Paris, 1891, July 6) in which the general principle is established that, under proper restrictions, *prismatic atoms possess atomic volumes proportional to their length.*

This proves, that *the first two additions of 16 each to the first member of the initial triad is made in the direction of the axis of the first atom.*

That is to say, the weight 16 added to Boron 11 joins it in the direction of the longitudinal axis of the boron atom (at right angles from the plane of the three valences), yielding the atom of aluminium; to this, in turn, the next increase of 16 is made in the same direction, so that the scandium, aluminium and boron atoms would appear in a longitudinal projection in the following manner: —

Bo	Bo
Al	Bo—16
Sc	Bo—16—16

Further, the reduction of the increase in volume with the increase in valence proves equally positively that *the original or first atom shows that valence in virtue of its structure*, and that the *increase* is added in the same manner.

That is, the divalent Be is a double body; adding 16 means the lengthening of each of these two bodies by 8; the next addition is again twice 8.

For the tetravalent C the body is quadruple; the addition 16 means one addition of four to each of these four parts of the carbon atom; and so on for all other elements.

If this be true, certain deviations must show themselves especially in the trivalent genera. But this is not the place to enter into further details. Facts of this kind have come to light in preceding parts of this little work.

Comparing next our charts Plate 8 and Plate 9, we see that the kaloids, cadmoids, styptoids and adamantoids begin with a triad, exactly as here brought to light; further, that the other genera do not begin with a triad, but with only two elements.

Examining our chart of atomic volumes, *we notice the same striking contrast;* for the initial lines of the chloroids, sulphoids and phosphoids *show only two points forming a straight line*, namely in the above order: Fl—Cl; O—S; N—P. If we from *the second* (Cl, S, P) pass to the *third* element (Br, Se, As) *we have to turn greatly aside from the first line* joining the first two elements, and we have in each case to *turn to the right.*

There surely are only *two parts* forming a prism in these negative elements, namely, the *first atom* and the *first addition of 16.* There is not, and there cannot be, a triad for these genera beginning with the *first* element of the same.

In these three genera we find the old *triads* beginning with the *second* member, namely, Cl—Br—Io; S—Se—Te; P—As—Sb. The first two form approximately (sulphoids) or accurately (chloroids) straight lines. The notable break or elbow in the phosphoids is associated with marked allotropy; our chart shows connecting lines for the *yellow* phosphorus, and also gives the location of the *red* and *black* phosphorus. We therefore need not enter upon further detail here.

Now, returning to the genera beginning with a triad (kaloids, cadmoids, styptoids and adamantoids) we see from both the second and the third member a triad turn off to the right also under *a very sharp break* in the line marking the atomic volume of the initial triad. Thus from silicon, the triad Si—Ge—Sn starts under an angle about 125 degrees with the direction C—Si—Ti. The triad Ti—Zr—Ce from Ti breaks off from the same line C—Si—Ti under about the same obtuse angle.

The same break we notice in every case; the angle varies, but the break is always strongly marked. So it is also, as above stated, for the electronegatives which show no initial triad; at Cl the triad Cl—Br—Io forms an angle of 130 degrees with the initial Fl—Cl. Even the argonoids show this character; the line Ar—Kr forms an angle of 140 degrees with the line Ne—Ar.

This angle is always obtuse for the upper triad, but may be acute for the lower triad. Thus the *upper* (light) Ca—Sr—Ba starts at Ca under an angle of 150 degrees, while the *lower* (heavy) triad Mg—Zn—Cd starts at Mg under an angle of about 85 degrees.

Here we meet again the question as to the relation of the cuproids. The *lower* triad, starting from Na, could only consist of Na—Cu—Ag, and would accordingly form the very acute angle of 40 degrees with the line Li—Na. This would not only be a very curious triad, but also be very slenderly connected by the very long line Na—Cu and under a most acute angle stated.

We must here again conclude, as we did above, that the relationship is very " distant " and " shadowy," and it is very much overbalanced by the closer relationship of the cuproids to the ferroid group.

We must now consider the meaning of the most striking *branching* of the middle triad volume line from the initial steep volume line of the first two or three elements of each genus. In this work it may be convenient to understand a few generally neglected facts, which already in our Programme of 1867 we have expressed in very simple terms.

The *atomic volume* of an element is the entire *space* occupied or maintained by that atom; we call it also the *atostere*. The real ponderable element atom actually fills only a very small fraction of this atostere in the gaseous state, and even in the solid state fills only part of the atostere; we must bear this in mind in all our considerations.

The space filled by the ponderable atom we have called the *atobar* (weight); its length the *atometer* (length) and its cross-section the *atomare* (area). Programme 1867, p. 6.

Now Plate 9 shows, in the rise of the initial part of the atomic volume line, the increase of this volume proportional to the atometer, as we have above found; the triad lines branching off to the right in almost parallel direction more and more approaching the horizontal as the genera descends to the ferroids, prove thereby that *the atobar is not lengthened in the last three elements of the different genera*, but remains the same that it is in the element from which the triad starts.

Thus the line of atomic volume rises rather steeply from Fluorine to Chlorine; but from this last element it passes to the right in an almost straight line nearly parallel to the base, showing that the atomic volume of Bromine and Iodine is nearly the same as that of Chlorine.

But the amount of material added is twice in succession three times as much as added to fluorine to form chlorine, which single addition greatly increased the atomic volume of chlorine.

This condition is quite general, as our Plate shows, for all genera of elements represented on the same. We therefore must conclude that *the atometer of the last three elements of each genus is nearly the same as that of the initial element of the middle triad.*

But this conclusion requires that the relatively large amount of matter added to the element at which the branch starts has been placed parallel to the axis of the atobar of that initial element of this middle triad; *it has enlarged the atomare, and not lengthened the atometer.*

This is precisely what we concluded from the study of the fusing points of the elements, namely, that the multiples

3 3 6

times the weight of (nearly) 16 *is added laterally, not in axially* to the lower members of each genus of elements.

From our mechanics of the three states of matter we know that in the liquid state the atoms revolve around the longer axis (for which the moment of inertia is smallest) the atometer of these element atoms is the direction of their axis of rotation, and the atomare the plane of that rotation. See *Notes* in Comptes Rendus, 1873, 1875, and later. Also Principles, 1874.

By the time that continued heating has caused fusion, when the atoms freely revolve around their prismatic axis specified, the cross-section of the atostere is so much longer than the atomare that an increase of the latter as here pointed out for each triad, will be insignificant.

Using the diagrams before given (Plate 10, the middle right hand side) we notice that the radius of the atobar for the first member of the triad being taken as unit, that of the third member will be 3 and that of the last member of the genus not quite 3.5. The radius of the atobar for Pb is therefore only one sixth greater than for tin, and has increased in the same proportion in the other genera.

Such an increase of the nucleus or atobar can have but a small effect upon the cross-section of the atostere; but the length of the atobar (or the atometer) measures the length of the revolving atobar which determines the height of the cylindrical space (atostere or atomic volume) of the element in the liquid state.

This, we trust, will suffice to make the inductive results theoretically understood; here the main thing is the fact — the theoretical explanation is of secondary importance.

RADIO ACTIVE ELEMENTS.

Supposing the constitution of the chemical elements be exactly as here confirmed by the study of their atomic volume (or specific gravity) and as first was found by our study of their fusing points; can we indicate, from the entire system of chemical elements, any genus that will admit more freely of oscillation of its constituent parts, than the others?

Calling the *first* or initial element in each genus a monad (True Atomic Weights, 1894, p. 213), and the next elements grown from these by the addition once or twice of 16, in the axis of the monad the *heavy dyads* (sulphoids) and the *light dyads* (kaloids) we have distinguished the following elements formed by the lateral addition of *three times* this mass (of about 16) *triads* and the last element resulting from the further addition of *six times* this mass we have called *hexads*. See Plate 8.

We have also called special attention to the fact that *generally* these triads and hexads *do not* show an increase in atomic weight of *the full limiting amount* of 3 times 16 or 48 units for the *triads* and 6 times 16 or 96 for the hexads; *but several units less*. We have also referred this peculiarity to the well known fact of organic chemistry, that *loss in weight of the combining radical produces a more intimate chemical combination.*

Thus Methane does not combine; it is not a radical, but a gas; its atomic weight is 16. One hydrogen removed gives methyl which is a radical of valence one; its weight is 15. The next radical, weighing 14, has a valence two, forming the so-called double links or bonds. Next we have the *tri-valent* radical 13, followed by *tetravalent* element carbon weighing 12.

We herewith may compare the adamantoids. Silicon 28, the dyad, increases but 45 to form germanium, which again increases 45 to form tin, which latter increases not even twice this amount (90), but one unit less (89) to form lead. Here we have in the triads each 3 units of atomic weight *less* than would result from an addition of the full 48 units, representing 3 times the fundamental increase of 16. The step from tin to lead takes place with a loss of 7 units; for only 89 units are added, instead of 96. Compare True At. Wghts., p. 220.

We cannot here state how many real atomic *ties* these specified numbers represent; that will depend upon the atomic weight of pantogen, which we do not need to consider here. But it will be admitted, that if an atom of hydrogen consists of the least possible number of pantogen atoms (which is two), the above numbers of *units* of atomic weights would represent double that number of atomic ties.

As a rule we therefore may say, that the greater the difference from 48 and 96 in the increase of atomic weight of the triads and hexads, the more firmly the atoms of the corresponding elements are tied, and the less chance there can be for intra-atomic vibrations of any kind.

The central portions of our system containing the trivalent and tetravalent elements, show an increase of 44 to 45, and 88 to 90 only in the styptoids, adamantoids and phosphoids (see preceding tables). Equally low are the additions in the Palladoids and Cuproids.

For the divalent cadmoids we find an average of 44 for the triads and 88 for the hexad; for the divalent sulphoids we have 45 and 47 (average 46) for the triads, no hexad yet being known.

For the monovalent kaloids we have 47 and for the chloroids about 46; for neither of these we know the hexad.

Evidently, all these genera of elements are held in their higher atoms (triads and hexads) by ties equivalent at the lowest to one unit of atomic weight in the triads (kaloids and chloroids). Quite a different condition of fact obtains for the calcoids.

Taking calcium as 40, we find a full increase of 48 to strontium and even 49 next to Barium. Unfortunately the experimental determinations of the atomic weight of strontium and barium are not above question. Nevertheless the accepted values give no room for any ties binding the constituent triad-additions in any way atomically; they seem to be merely in molecular combination.

Accordingly, *we may expect a wider susceptibility to intra-atomic vibrations in the atobars of the calcoids than in the atobars of any of the other elements.* Common experience has long made chemists familiar with the remarkably brilliant light of the ignited oxides of this group.

In the titanoids we find somewhat similar conditions. Titanium exceeds the estimated atomic weight 44 by 4 units (indicating mobility at the second link of this dyad), and cerium and thorium are the essential radiators in the Welsbach light. Unfortunately, the atomic weight determinations in this group are also far from satisfactory.

But it will be immediately recognized that thorium is an element of pronounced radio activity.

The Molybdoids increase by 44 and 89 from chromium to molybdenum and wolframium. If uranium were to be placed in this group it would show an enormously *high* increase of 55 for a third triad; but such an element we cannot accept, therefore uranium cannot belong to the molybdoids.

Accordingly, uranium will have to be placed as one of the heaviest of the class of the metals of the rare earths, and thus fall diagonally in line with the radio-active thorium which is supposed to have an atomic weight 9 less than that ascribed to uranium. See Plate 6.

This agrees admirably with the fact that uranium and thorium both are pronounced radio-active elements.

The hexad of the calcoids is the supposed element radium, which possesses radio activity in the highest degree. We have already considered its supposed atomic weight. The value given by the Curies (225) was shown to be low, while that indicated by its spectrum (258) is quite high.

Any value above 232 (for Ba 136) or 234 (for Ba 138) would imply the *full number* of 96 units added to the barium to obtain the corresponding hexad.

If the atomic weight of radium shall be found at least 233, there cannot be any chemical ties in this hexad; its addition of six times 16 units is not restrained by chemical atomic ties from oscillatory motions.

But we do not wish to go too far on this ground. We need very excellent atomic weight determinations to form a basis for this structure. The facts as known bring the radio activity of these three elements in so close relation that the atomic weight determinations ought to be undertaken in a truly rational manner.

THE DECOMPOSITION OF THE ELEMENTS.

Starting with a substance, supposed to be a compound of "radium," an English chemist has recently obtained an "emanation" which he supposes derived from the supposed element radium. Another very noted English chemist has observed the "helium lines" in this emanation, at least for a short time, after which there remained — it is not stated what.

Again, a noted physicist of one of the famous old English universities, has determined the "mass" of certain "radiations," supposed to be "electrons" and finds this "mass" of the electrical radiation about one thousandth of the mass of an atom of hydrogen. Hence — *electricity is moving mass*, and matter is composed of electricity, about a thousand "electrons" to one atom of hydrogen.

These contrasting views remind us of the conditions two centuries ago, quaintly expressed by *Voltaire*, who left the world full of matter in France, but found it to be absolutely empty upon his arrival in England. The "energetic" chemist of Leipzig denies matter; the physicist of Cambridge weighs electrical energy in ponderable atoms of hydrogen.

In the scientific literature of the day, these most astonishing conclusions are accepted without much questioning. Here in St. Louis, in the great "Government Building," thousands of people are told by a young "lecturer" twice a day, "at the expense of the Government" these same conclusions as practically established facts; adding a nice determination of the "life of an atom" by giving it a "round number of thousand years " so that the audience, mostly ladies, will not witness the agony of any expiring atom.

To present to the general public as established scientific facts a lot of fairy tales, illustrated by experiments of a taking kind, properly " all in the dark," is a sort of missionary work in " modern science " that to some of us will appear a very questionable enterprise, especially when carried out at national expense.

" Our Government " in this great building is instructing its people in a very queer way even as to simple plain facts of common observation — of course, always in splendid form, since Uncle Sam has money to burn by the million. Surrounded by the collection of chemically most important *cosmical materials* stands in elegant frame a big and beautifully finished map of the United States, showing by *blue stars* where these meteorites have been found, and by *red stars where they have been seen to fall.*

The town of *West Liberty*, *Iowa*, is marked by such a red star; but it is a notorious fact, that no meteorite was ever seen to fall at or near that town, nor was any meteorite ever found at or near West Liberty, Iowa.

In its official " Catalogue of the Meteorite Collection of the United States National Museum to January 1, 1902 " (page 685), published by the *Smithsonian Institution*, " for the *Increase* and *Diffusion* of KNOWLEDGE among Men per Orbem " we read *West Liberty*, *Iowa County*, *Iowa*, as the locality. But outside of the National Museum and the Smithsonian Institution nobody knows of any town or post office " West Liberty " in Iowa County, Iowa.

Examining this grand official Meteorite Map of the United States a little further, *we find Iowa County*, *Iowa*, *without any meteorite mark;* yet it is known in scientific circles throughout the world, that one of the grandest meteors was seen on the evening of February 12, 1875, throughout the Northwest, and that *many large meteorites fell on that occasion in* IOWA COUNTY, IOWA, mainly in the *Amana* Colony. I have personally collected and studied about one hundred of these meteorites, the aggregate weight of which is much over two hundred kilograms, or about five hundred pounds.

Such is "*Government Science*," represented at our World's Fair. Is State-Science to be as bad as history claims to have proved the State Church?

But it is useless to contend against the scientific errors promulgated by the millions appropriated by our National Government whether in regard to Radium, meteorites or atomic weights. Though profoundly convinced that the elements are complex and not simple in their nature, but built up from one single kind of matter, and though I have now worked carefully for half a century to get "more light" on the precise complex structure of these elements by means of a thorough study of their physical, chemical and crystallographic properties by the aid of the known laws of general mechanics, I must confess that I have been unable to accept any of the so-called experimental demonstrations of the chemical decompositions of any one of our elements.

Let us examine the conditions of a possible decomposition of the chemical elements from our point of view.

First, we may admit that there is some valuable evidence that certain genera of the elements are less rigidly constructed than the great majority thereof; such a group of elements we have pointed out in the higher metals of the rare earths.

The keen chemical sense of Schützenberger directed his work to this very group.

Second, the "*complex 16*" which we have found so prominent in the structure of the chemical elements, and which is laterally combined by ties of different firmness (reminding us of the different bonds in our modern organic compounds), may *possibly*, in some cases, be "broken up" and then most likely yield some sub-multiple thereof, *possibly* the nullovalent element of atomic weight four, which we call helium.

But what energy will it require to loosen one of these bars and to break it up? It sometimes seems as if our most emphatic chemical advocates of "energetics," who even go so far as to deny the existence of matter, are forgetting some of the fundamental facts of the conservation of energy.

In my Elements of Chemistry (1871) and in my Principles (1874) I have tried to represent chemical energy by a difference in level; the diagram shows hills of the metals down the steps of which chlorine flows as water flows down over mountains and cataracts. I called it the *chlorine cataract* and gave the relative heights according to well known determinations. Monsieur Berthelot, in a letter of March 16, 1875, on the "Principles" commended the presentation of this general topic very especially. I trust he will pardon my mention of this fact.

I am here reminded of M. *Berthelot* because I pointed out the the mechanical significance of a fact which he first had specially called attention to, namely the radical difference presented by the specific heat of elements and compounds. See my *Note* XXIII presented by M. *Berthelot* on the 25th July, 1892, to the Academy of Sciences of Paris.*

In the following words I explained this *radical difference* between elements and compounds mechanically: —

> " In chemical compounds, the chemical atoms are contained as " integral individuals, retaining their own proper motion of vibra-" tion; but *the atoms of the true chemical elements are solid or* " *rigid*,† *bodies* of which the constituent atoms have no " individual motions."

In other words, the constituent atoms of pantogen have lost their mechanical individuality by being *rigidly* united to a single body (the element atom); the individual pantogen-atoms do not separately vibrate, have no individual motion of vibration or of any other kind; *the element-atom is one rigid mass.* This is demonstrated by the specific heat determinations of the elements here involved.

In a letter to the perpetual Secretary I indicated (at the time) the enormous expenditure of energy that would be required to effect the *separation* of these pan-atoms or the association of the element atoms. Possibly we shall be able to accomplish this by means of electrical energy, some time; but there seems to be no immediate prospect of doing so. At least I cannot find any experiment having accomplished this.

---

* Comptes Rendus, Tome 115, p. 239; 1892. — This Note was republished in *Chemical News*, London, Vol. 68, p. 171; 1892.

† The misprint " liquides " for " rigides " in the C. R. is very annoying.

I am astonished at the present utter disregard of the fundamental laws of physics and mechanics which successive generations of great men have established from Galileo, through Huyghens, Newton, Leibnitz, to the much praised modern Clausius, Mayer and Helmholtz. I had the honor of a personal acquaintance with *Colding*, of Copenhagen, whose famous tribometer first proved the relation between heat and mechanical work here involved.

Now I must insist that to effect a chemical decomposition of a combination more intimate than that of the elements with one another will require an enormously greater expenditure of energy than the decomposition of water.

The decomposition of water, or sodium chlorides, requires an enormous amount of energy as compared to that required to decompose complex organic substances. Yet, while some of these latter compounds decompose by contact with water, we are expected with our most noted chemical philosophers of the day to accept that sodium chloride also decomposes by such mere contact (solution). Professor Winkler has recently called attention to the fact that Crookes pretends by mere treatment with ether to separate certain uranium compounds, the radio-active from the non-active.

But enough. There has not yet been presented any experimental evidence of any decomposition of any chemical element, so far as I am able to judge.

I shall be delighted to recognize such decomposition as soon as it shall have been accomplished; for it will confirm the fundamental principle of my mechanics of the atom, and greatly encourage further work in this science.

In conclusion it may not be amiss to recollect the striking disappointment of the chemists who almost half a century ago experimentally tried to obtain Ethyl and Methyl. The reaction took place exactly as anticipated — but of course these radicals did not appear in the manner expected: they appeared necessarily mutually combined as saturated hydrocarbons.

Accordingly, when we shall have decomposed the higher elements and go to gather up the pantogen — we may find some simpler, less complex elements, especially helium and hydrogen.

THE IMPORTANCE OF ANOMALIES IN THE DETERMINATION OF THE FORM OF THE ATOMS.

It lies beyond the plan of this popular introduction to give special information on the determination of the form of the atoms of compounds by means of the thermometer; most of my NOTES published in the Comptes Rendus contain applications of the principles already set forth in the *first* one of 1873. In the BEITRAEGE of 1872 the general principles were already expressed by general formula. In my *Principles* 1874 this subject was also quite broadly presented; so also in my *General Chemistry* of 1897.

Referring to this extended series of publications for details, I shall here only attempt to show two of the most interesting and most important *anomalies* according to the *Rule-of-Three theory* of *Kopp* which still flourishes in Germany.

When *Hermann Kopp* in 1872 kept my papers, referred to him by the German Chemical Society,* he thus perpetuated his *Rule-of-Three Theory* — and kept German Chemistry stationary, and left German Chemists in ignorance on this most important field of investigation. Even *Traube* in his recent work (Physikal. Chemie, 1904) remains sixty years behind, and does not seem to have any knowledge whatever of the work of half a century.

The most striking *anomaly* in the view of this stagnant German school of *Kopp* is *the lowering of the fusing or boiling point by an increase of atomic weight.* We have seen this "anomaly" to mark the metallic genera of the elements.

In order to give a couple of examples of our work done on this ground, we print here Plates 12 and 13 from the first part of our special work on the mechanics of the three states of aggregation, which was really intended to form part of this book, but had to be omitted for lack of time.

In Plate 12 we show a series of the lowering of the fusing point by an increase of the atomic weight, while in Plate 13 we give a most striking case of the same kind for the boiling point.

The Plates give really all the necessary information, and constitute striking cases of our method of geometrical investigations

---

* See letters and documents in my Beitraege, edition 1892.

in physical chemistry. Only a few general explanations may here be added.

FUSING POINT ANOMALY.

In Plate 12 the upper oblique heavy line (almost straight) connects the fusing points of the most important *Acetamids;* the formula is given below the word. The one dash indicates that the acetamid-radical is monovalent.

Below, and almost parallel hereto, is found the line connecting the fusing points of the *Formamids*, in the same manner.

The more steep dotted lines represent the positive radicals (hydrogen, phenyl, phenmethyl, phenethyl), the chemical formula of which are also given on the plate. It will be noticed, that these four lines are also very nearly parallel.

By two such systems of lines, we can determine the fusing point of compounds not yet known. Even the fusing point of phenacetin was fairly well determined from acetamid and acetanilid before it had been made.

Every point here represented shows the absurdity of the school of *Kopp* still dominant in Germany.

However, the changes thus far spoken of may be called normal as to sign, for the fusing point rises with increasing atomic weight.

But it does not increase at a fixed ratio, for the full drawn lines of the negative radicals are much less steep than the dotted lines of the positive radicals.

If we were to imitate the most popular German leader in physical chemistry, we might say the *Choneutism* of the negative radicals is much in excess of the *Choneutism* of the positive radicals. It might, perhaps, be more philosophical to use the term *Choneutotropic;* I shudder at the responsibility of deciding so profound and weighty a question.

But let us get out of the philosophic atmosphere of Leipzig and consider the facts before us. By a simple measurement we find that at the point phenacetin the line marked negative radical forms an angle of 14 degrees, while the line marked positive radicals* is inclined 70 degrees to the base or atomic weight

---

* Along the line marked *negative*, the *positive* radicals vary.

abscissa. We also notice that the temperature scale numerically is exactly half the atomic weight scale.

Since now the tangent of 14 degrees is 0.25 and that of 70 degrees is 2.75, the increase in fusing point *per hundred* in atomic weight

is 50 degrees C. for the positive radicals,
but 550 " " " negative "

To return for just a moment to Leipzig we might say that choneutropic force of the negative radicals is eleven times as great as that of the positive radicals — and then rest again.

But leaving nonsense (I mean to say, modern scientific philosophy of physical chemistry) aside, we simply must state that the much greater *steepness* of the dotted fusing point lines shows that the fusing point rises with an equal increase of atomic weight eleven times as much for a change in negative, as for an equal change in positive radical. There certainly is no change for the "rule of three" here.

But perhaps it is the atomic weight of these radicals that influences these remarkable relations. The atomic weight of the positive radical phenethyl (of which the full formula is given on the plate) is 121 while the atomic weight of the negative radical acetamide (also given on the plate) is 58. This is roughly one-half of the first. Most assuredly nothing comparable to the ratio one to eleven.

But if so great numerical differences occur as to *rate* we ought not be surprised to find even the sign of the change becomes reversed. So it does in fact.

Looking at the dot marked Phenacetin, we notice a faint line drawn from it obliquely down to the right, on which a dot (fusing point) marked Me is entered. Further down this line we find an arrow pointing down and marked Et.

This means that if in the acetamide radical of phenacetin the last atom of hydrogen is replaced by methyl, the fusing point is lowered to the point just specified and marked Me, while if the same were replaced by Ethyl it would lower about as much again and fall below the margin of our plate.

By in this manner increasing the atomic weight of phenacetin by 14, the fusing point falls almost one hundred degrees; if the increase of the atomic weight is doubled, the *decrease* is also roughly doubled.

If we turn to the older compound *Acetamid* we find on our plate *two* lines drawn therefrom to the right and downward, *showing a rapid fall of fusing point with increasing atomic weight*, namely —

1, the *full drawn line* marked by the *black* circles: Me, Et, Pr represents the *falling* fusing points of Acetamid in which the last (amid-) hydrogen is successively replaced by the radicals Methyl, Ethyl and Propyl which *increase* the atomic weight by 14, 28, 42 respectively; and

2, the *dotted line* marked by *open* circles Fo, Ac represents the corresponding substitutions by the acid radicals Formyl, Acetyl, increasing the atomic weight respectively 28, 42.

It will also be noticed that the *difference* between Ethyl and Formyl substitution and between that of Propyl and Acetyl is but very moderate; the corresponding increase in atomic weight being for the first 28 and for the second 42. Nevertheless there is a difference in the results, so that even this is not a simple matter of atomic weight. The rule of three finds no resting place anywhere hereabouts.

From what has been shown it appears that, as a matter of fact, the fusing point may rise slowly or rapidly, and it may even fall rapidly for a given increase of the atomic weight.

This *may* be called a "*constitutional*" difference, and not an "*additive*" difference and the Leipzig school would rest while we would know nothing about it. Even the *fact as such* has never been brought out as strikingly as here in our graphical representation which we suppose to be new; we have used it for years.

It is just this sort of *anomalies* that are helpful to the true investigator, for they lead to the truth after having shown themselves inexplicable on all common suppositions.

By just such cases the rotation of the atom in the liquid state is demonstrated to be around the natural axis for which the moment of inertia is a minimum. The series of publications introduced must be consulted by those who would study this subject more thoroughly. Here in this popular outline, we merely wished to impress upon the reader that really something worth consideration has been done in this field, though in the words of Ostwald (Electrochemie, 1896, p. 879) "the "influence of a few men controlling scientific opinion * * * "made the consideration of the work * * * to be regarded "as useless."

BOILING POINT ANOMALY.

On Plate 13 we give a striking case of the same general character for the boiling point. All necessary data and formulae are entered upon the plate, which should be studied with special care, since we can only devote very little space to it here in the text.

On the lowest line 1 marks the observed boiling point of water; 2 that of sulphuretted hydrogen also observed; 3 the corresponding compound of selenium, also observed; 4 that of tellurium by our graphical interpolation.

It is a commonly known (but very rarely stated) anomaly, that the boiling point of water is almost 180 degrees higher than the boiling point of hydrogen sulphide; for the atomic weight of oxygen is 16 and that of sulphur is double the same, 32, which would according to *Kopp* and his German school of to-day require the opposite *character* and much less in amount. When, however, this S next is replaced by the heavier atoms Se and Te, the boiling point changes normally by a very gradual rise.

It will be seen further on our plate, that when one atom of hydrogen of the water is replaced by an *alcohol* radical, *the anomaly remains, but greatly diminishes in amount* for the thus resulting ALCOHOLS.

Need I say that we have here facts comparable to the gradual diminution of the contrast or *discontinuity* so strongly marked in the succeeding orders of the elements?

If now also the second atom of hydrogen of the water be replaced by another alcohol radical, so as to obtain the ETHER, *the anomaly has not only disappeared, but the increase from* 1 to 2, that is, from *oxygen to sulphur* is much more considerable than the increase from sulphur to selenium, and from selenium to tellurium.

Indeed, *the boiling point lines for* corresponding *alcohols and ethers* are *concordant* for S, Se,Te, but *symmetric for oxygen:* rapidly descending for alcohol, rapidly ascending for the ethers, with the *increasing atomic weight* from oxygen, 16 to sulphur, 32.

These conditions are an exact repetition of what we have found when studying the fusing and boiling points of the elements.

No more striking facts can be found in any part of physical chemistry; but still, these marvelous facts are not generally known, hardly ever alluded to — because the rule-of-three introduced by *Kopp* still remains the rule-of-thumb in the German works on physical chemistry, and a few men in high official position so control scientific opinion that the rank and file do not deem it necessary to study such publications as mine in the Comptes Rendus of the Academy of Sciences of Paris, even though they were presented by one of the foremost scientists of the nineteenth century, by Monsieur Berthelot.

I may be permitted to quote a few prophetic (and approving) words from a letter of *Berthelot* of October 9, 1891: "I must "compliment you on your new results and on the methodical "sequence and the elegance of your deductions: I can have no "doubt they will make an impression *unless statical atomism* "*throws a veil over the minds*" (of the chemists). Our work was dynamic (rotation, moment of inertia); the prominent professors of chemistry are hardly even in statical chemistry, but in rather a sort of *statical atomism* represented in structural formula without regard to really statical forces. Instance the tetrahedron of so-called stereo-chemistry. See General Chemistry, 1897, p. 335.

As we cannot here enter upon the analytical treatment of the subject of the rotation of the molecules (which would require a book, the introduction to which are the 140 pages quarto published as Notes in the Comptes Rendus, thanks to the scientific spirit and independence of *Berthelot*), we must close this subject with the following statement that probably will be understood by all: —

The moment of inertia of any system of atoms depends more on *the relative position than on the weight of the atoms; for the influence of each weight is multiplied by the square of its distance from the axis of rotation.*

I may add that the "*Anomaly*" in question furnishes, when examined in detail by my calculation of the moments of inertia, a most absolute demonstration of the result above arrived at, namely, that the atometer of the triad S, Se, Te is the same and about double that of oxygen.

Thus gradually the relative dimensions of the atoms are determined, not only by *one* method of procedure but by *concordant results* obtained on different lines marked by the different fundamental properties of the chemical elements.

In conclusion I beg permission to refer to another striking anomaly, the variation of the fusing point of aliphatic compounds with the number of carbon as *odd* and *even* in the same. This anomaly is *stated* in larger text-books also in *Traube's* recent book (1904, p. 203) for *Baeyer* detected this anomaly first and he must be mentioned. This anomaly was fully accounted for in my Note X (1891, July 8) and used to determine the linkage of the carbon atoms, Note XI (1891, Aug. 17). Why does not Dr. *Traube*, whose mind is not entirely controlled by that of *Ostwald*, study the Comptes Rendus on the subject of this "interessante

Schmelzpunktsunregelmaessigkeit,"

if I may be permitted to use his own impressive terms.

THE FORM OF THE ATOMS.

We have now obtained a fair knowledge of the general form of the atoms of the chemical elements. Starting with the monad of definite electrical character and valence, the elements of each genus result in the manner stated, first by axial addition of 16, next by the lateral regular addition of 3, 3 and 6 times this amount.*

---

* The nullovalent elements seem to possess a different structure, if their atomic weights commonly accepted are reliable. They seem to prove a quadratic structure and a corresponding increase on the sides thereof, followed by increase in depth or thickness according to the ratio: 1: 5: 10: 20: 30, where the unit He is 4. This would account for most of their distinguishing properties.

We have not yet treated of the form of the element atoms of the first order, the monads, beyond the incidental demonstrations that they must consist of as many bars as the number of their valence. We ought yet to obtain some definite idea as to the reason of that wonderful contrast of the monads, from oxygen and nitrogen, through carbon and boron to beryllium and lithium, which we have termed the most extreme discontinuity in nature.

In order to do so we must recall the general mode of enchainment of the atoms in chemical compounds, first shown in our Programme of 1867 (p. 12–13 for the typical compounds) and fully demonstrated in our Note XI, 1891.

Accordingly, serial organic compounds are typically represented by the upper figure of Plate 14, showing first the horizontal projection of the five atoms of carbon, and below the entire axonometric drawing of the atom of pentan. The three co-ordinate axes are shown, so that the co-ordinate of the center of each one of the constituent carbon and hydrogen atoms may be read off.

Such axonometric drawings are described in my Principles, 1874, where I called them *stereographic* formulae (pp. 63–64, Plate I, Fig. 4), as well as in the Programme, 1867, p. 14.

The general forms of the serial compounds like pentan is therefore *prismatic*. On this basis, the molecular volume of organic compounds was determined in our Programme, 1867, in our Contributions, 1868, No. 2, in our Principles, 1874, p. 115–117, and in our Note X, 1891.

In the lower half of Plate 14 we have given our horizontal projection of an atom of benzol; the axes X and Y are shown, Z is vertical in the center or origin O.

The back of the carbon atoms are shaded by lines, the face is left open. The significance hereof is best shown in the upper figure, and must be borne in mind for properly understanding the position in space of the six carbon atoms of benzol.

By the way, the latest work on Stereochemistry by *A. Werner* (Jena, 1894), does not refer to me, while *C. A. Bischoff* (Frankfurt, a. M., 1894) refers to me in a foot note (p. 15), quoting from *Lothar Meyer's* famous review * of my Programme (see

---

* Zeitschr. f. Chemie, N. F., Bd. 6, p. 446.

True Atomic Weights, 1894, pp. 239–255), in a most demonstrative manner, showing how thoroughly *Lothar* did his work.*

It is truly marvelous how the modern chemical world has been misled by a few German chemists into the absurd tetrahedral stereochemistry which itself has been publicly disavowed by its originator *van't Hoff* of the University of Berlin as "childish" in his address† at the Dalton Celebration in Manchester, May 20, 1903 — twelve years after I had proved its mechanical absurdity in the Comptes Rendus (Note XI, Aug. 17, 1891).

It might well be asked how it is possible that Professor *Werner* in 1904 can issue a "Lehrbuch" of 500 closely printed pages octavo, based upon a principle proclaimed early in 1903 by its own author to be "childish" and which had been proved absurd by me in the transactions of the Academy of Sciences of Paris in 1891.‡

After all, I am inclined to cordially thank Professor Werner for having omitted my name from this book of his, but I beg to be permitted to express my regret that such books are in fact the sources which the multitude of young chemists are advised to study to-day.

But with *van 't Hoff* and *Ostwald* at the head of a great organ, their "Zeitschrift für physikalische Chemie" anything seems possible. The dreadful effect on the progress of science of such an influence of a few scientific men, having control of public scientific opinion, has by no one been more thoroughly exposed than by *Ostwald* himself on pp. 879 and 880 of his Electrochemie, Leipzig, 1896.§

Ostwald says that "the weight of this opinion depressed the regard for those contributions to such an extent, that even those

---

* Meyer "hebt als verdaechtig hervor" * * * dass Hinrichs * * * "operirt mit dualistischen Formeln" * * * "alle Betrachtungen auf die als *irrig erkannte* (sic!) Proust 'sche Regel basirt." * * *

† Science, V. 17, p. 955; 1903, from *Nature.*

‡ The collection of experimental data in Werner's book is most valuable and ought to show him that they are in full accord with the chemical structure as represented in our work.

§ I just see a report on the Radium lecture by *Ostwald* before the Chemical Society in the Royal Institution at London; how *Faraday* would have spoken, if he had been present!

scientists not immediately concerned were deterred from giving personal examination to the contributions which had been discarded with such energy.*

Probably this accounts for the fact that a younger American chemist of prominence, a professor in one of our largest Eastern Universities, and the editor of a chemical journal, in a friendly chat of chemists during the last meeting of the American Association, at St. Louis, about New Year, 1904, declared with some show of pride and satisfaction: "I know nothing about the form of atoms."

If this bright disciple of *Ostwald* had not been blinded† by the crude and forceful teaching he received at Leipzig, he would no doubt have looked into the Comptes Rendus with open eyes and without prejudice — and I am sure, he would have easily understood the fundamental points about the form of the atoms of organic compounds.

Having now possibly pushed away some cobwebs that, as Ostwald declares emphatically, some time are spread by men in high scientific positions like his, to the great loss of science and to the lasting injury of the rising generation of scientists, we may expect that the unbiased reader has acquired an idea of two forms of compound atoms, the *prismatic* and the *tabular* or discoid.

---

* It is extremely difficult to translate so loosely verbose a philosopher (Naturphilosoph) as *Ostwald;* I therefore transcribe his original German from which we have taken the main parts.

Dieser Umstand drängt zu der andern möglichen Auffassung hin, dass es in der Thatder Einfluss einiger im Besitz der damaligen öffentlichen Meinung befindlichen Physiker war, die sich MAGNUS, dem ausgesprochensten Gegner HITTORF'S, anschlossen, und durch das Gewicht ihrer Meinung den Credit jener Arbeiten in solchem Maasse verminderten, dass auch die nicht unmittelbar Betheiligten sich einer genauen Prüfung dieser mit solcher Energie abgelehnten Arbeiten uberhoben glaubten.

† Ostwald, same page already quoted from, says: —

Kamn man sich denken, dass zu jener Zeit sämmtliche Geister so mit Blindheit geschlagen waren, dass sie diese einfachen Dinge nicht sehen konnten?

Indeed, we need not *imagine* such a sad condition, but have seen it exemplified for a dozen years by the organ of *Van't Hoff* and *Ostwald.*

These forms are exemplified, the first by the *aliphatic* (or alcoholic) organic compounds, the latter by the *aromatic* compounds.

Next, we must ask the reader to remember that we, by strict mathematical deductions, have determined from these forms the fusing and boiling points of enough series of organic compounds to prove the reality of these forms by the concordance of the calculated and observed boiling and fusing points.

We may therefore properly call these terms of the compound atoms — prismatic and tabular — demonstrated by the thermometer's indication of boiling and fusing points, exactly as the form of the earth has been demonstrated by a corresponding train of exact mathematical deductions together with the observed oscillations of the pendulum at distant points on our globe. These two cases of investigation are exactly parallel; and from all we know by their writings, both *Ostwald* and *van't Hoff* would have ignored or ridiculed the mathematicians and astronomers who determined the form of the earth by the pendulum, as they have ignored or ridiculed my work of determining the form of the atoms, for they are unable to comprehend the mechanical steps involved in both of these important researches.

Now, it has long been demonstrated by mathematicians in that great branch of this fundamental science called *analytical mechanics*, that the two principal permanent axes of rotation for any body or any system of rigidly connected bodies (say the atoms of a chemical compound) are determined by the weight and position of the parts or particles of the body or system.

For a sphere, the maximal and minimal moment of inertia coincide, their *ratio is one*, and really any diameter of a sphere is a permanent natural axis of rotation.

For a circular disk the axis at right angles to the disk at its center has the *maximal* moment of inertia, exactly *double* the *minimal* moment for any one of the diameters of the disk.

For a *prismatic body* — a rod, or a bar – the *minimal* axis coincides with the geometrical axis, while the *maximal* axis is at right angles to the bar at the center of the same; and further the *ratio* obtained by dividing the maximal moment by the minimal moment *increases indefinitely* with the length of the prism.

Now, since we have demonstrated in the publications specified, which have been issued during the last forty years, that the *fusing point* is determined by the *minimal moment*, and the *boiling point* by the *maximal moment* it follows, that

for alcoholic or aliphatic compounds, the atomic form being prismatic, the fusing and boiling point curves must greatly diverge with increasing atomic weight; while

for *aromatic compounds*, the atomic form being tabular, the fusing and boiling curves must run mainly parallel to one another.

Plate 15 represents the observed fusing points (black circles) and boiling points (open circles) of the hydrocarbons as ordinates to their atomic weight as abscissae.

We see that the curves for the prismatic paraffins diverge, while the curves starting from *Benzol* respresenting the aromatic hydrocarbons run mainly in parallel direction.

This great general fact has never been accounted for — and indeed, has practically been overlooked; but it is very real, and though its strictly mathematical demonstration may not be comprehended by all, it will be admitted by all who have the necessary mathematical training.

Before we make any application of this fundamental relation to the chemical elements, it may be advisable to show one of the striking applications hereof to certain dominant but scientifically unproved chemical opinions. It is universally believed by modern chemists, that the substituted atoms in the so-called *para* compounds are *opposite*, while in the *ortho* position they are *neighboring* places in the benzol atom or as it is commonly called, the benzol ring.

It is greatly to be regretted, that the designations ortho and para *based on actual derivation*, have practically disappeared from the pages of our chemical literature and have been replaced by the numerals 1, 2 and 1, 4 expressing the *supposed* places above given.

Now, in my numerous and very laborious calculations of the moments of inertia, I have also calculated the two moments for substitutions in the benzol atom (Plate 14) in neighboring (actual places 1, 2) and in opposite (actual places 1, 4) places.

The result was that *the ratio* of the two moments *is greator for the opposite than for the neighboring substitution.*

That means, the fusing points must be lower for opposite substitution, higher for neighboring substitution, since the maximal moments do not vary much.

Plotting the actually observed *boiling-fusing* points of the para and ortho compounds, as shown by Plate 16, we find indeed the corresponding boiling points practically the same, but we see that the fusing points of the ortho compounds are throughout much lower than the para compounds.

According to our so generally confirmed mathematical principles we must therefore conclude, that

the para compounds are neighboring

or 1, 2 *substitutions*, and

the ortho compounds are opposite

or 1, 4 *substitutions.*

This crucial test therefore proves that the opinion universally taught by all modern structural chemists cannot be true, unless it be shown that the entire system of our atom-mechanics is false.

As a preliminary step to obtain such a demonstration it will be necessary for our modern structural chemists first to study this our system of atom-mechanics.

It may be a little hard to begin this not easy study; I can assure the structural chemist that it will take solid mathematical training and not mere "childish play with tetrahedrae."

If that study is undertaken, I venture to say, that there will be a total change of heart, that the scales will fall from the eyes of our modern chemists.

But it is unbecoming for me to picture the result; I will let *Ostwald* express it: —

"Zwar spät, aber dann um so nachdrücklicher hat sich die
"Anerkennung dieser klassischen Arbeiten Bahn gebrochen,
"und zwar durch den Umstand, dass auf andern Boden That-
"sachen entdeckt warden, welche zu der gleichen Auffassung
"drängten." l. c. pp. 879–880.

Of course, *Ostwald* is always extravagant in his statements, and therefore too complimentary; we will not say that our work is classical. But we dare say, that we have retraced every step carefully, these many years, and we have taken every possible care to avoid errors.

For that reason we feel confident that the statements made by us, in all essential particulars, will be confirmed by every conscientious and really competent investigator who shall now or at any future time repeat our calculations.

And since now " on another ground facts have been discovered which lead to the same conclusion " (to repeat part of the last words of *Ostwald*) we may really expect that our work will receive general attention, since to-day chemists appear no longer to shy at our *first* statement that the chemical elements really are compound bodies.

We admit, that the "Radium-Craze," as *Winkler* so appropriately has called it, takes quite too easily to the notion, that some of our elements *have* been decomposed already; but if our modern chemists are bound to be led astray, may they not for once through error get into the right way?

Since they now without an effort begin to think of the elements as compounds, we may hope, that the younger generation will undertake the study from which for forty years chemists have been deterred by this false notion that our very starting-point was wrong.

Hoping that the reader now has acquired a reasonable conception of the form of the atoms of compound bodies, we may turn back to the form of the simplest of all chemical elements, the monads or elements of the first order consisting of but one single group of pan-atoms.

Not able to present our full work on atomic forms in this popular outline, we must here confine ourselves to a statement of final results deduced, followed by some explanatory remarks.

We therefore state, as the final result of our investigations, that the general form of the monad atom is *prismatic* for the true metalloids, which are pronouncedly electronegative, and that it is *tabular* for the true metallic monads and for boron and carbon.

In other words, the metalloids correspond to aliphatic compounds, while the metals correspond to aromatic compounds. Or, again, the prismatic element atoms are electro-negative, the tabular atoms are electro-positive.

The four double disks of a carbon atom may group molecularly in three forms at least, which may correspond to only single, or including double and treble atomic ties; the second probably is graphite, the last is the diamond. Such a body will show an enormous cohesion and relatively high density or very small atomic volume. This implies highest fusing and melting point.

From this central form, we have tabular forms towards the metals, prismatic towards the metalloids.

As the valence becomes less, that cohesion will be lessened, a less number of parallel forms being present. Hence fusing and boiling points will be lowered; from general mechanical principles we conclude the temperature change to vary in a geometrical ratio while the number of components (i. e. the valence) varies in an arithmetical ratio. The valence represents approximately the logarithm of the temperature change.

The effect of the axial and lateral increase of the monad by the sixteen-group in the manner so often specified, will gradually make these common masses added dominant and thus make the higher members of the genera more nearly alike in their physical properties.

THE ATOMIC WEIGHT OF PANTOGEN.

It now remains to determine the atomic weight of primitive matter, the pantogen.

Since hydrogen has the lowest atomic weight of all elements and is taken as one, it follows that the atomic weight of pantogen depends on the number of pantogen atoms combined to form one atom of hydrogen.

We have from the first, been convinced that the number is two; all our extended examinations have confirmed this result.

Therefore the atomic weight of pantogen is one half that of hydrogen or one thirty-second that of oxygen.

The atomic number of any element is the number of pantogen atoms forming one atom of that element.

Hence the *atomic number* of hydrogen is 2, of oxygen 32, sulphur 64, silver 216, lead 414.

The laws of symmetry make the even atomic numbers much more probable than the odd atomic numbers. This is confirmed by the fact that we find really only two elements, namely, chlorine 71 and copper 127, for which the odd number may be considered established.

All other elements having an even atomic number, therefore, must have a whole number for atomic weight if the atomic weight of hydrogen be taken as one.

Now, this statement is denied by a majority of the chemical world, especially by the official part thereof, which has combined in the issue or annual proclamation of atomic weights, called international atomic weights.

The question at issue is not the amount of difference, the insignificance of the numerical value of the fractions, but the very existence thereof. It is a question of principle of highest importance; for on the final decision thereof depends the recognition of the unity of matter.

We have fully examined this question in the fourth series of our Notes (Nos. XXV to XXXIII) and especially in our two works:

The True Atomic Weights, 1896, and

The Absolute Atomic Weights, 1901.

It is impossible to briefly consider the main points in a popular form in this place; the present book has already passed by far the limits originally set for the same.

We therefore must refer those of our readers who desire to examine into this great question to the above works of ours, especially the last named one.

CONTENTS.

Halftone-Portraits with Autographs of Seven Eminent Scientists who have assisted the author.

List of Publications on Atom-Mechanics VII

Characteristic Properties, Genera . . . . page 1
Boiling-Fusing points 9
Atomic Weights of the Elements 11
Fusing Points and Atomic Weights 14
Fusing Points and Valence* 24
The System of Atomic Weights† 42
Total Number of Elements and the Cosmochemical System . . . 47
Frequency and Distribution of the Elements 50
The Atomic Volume of the Elements‡ 52
Radio-active Elements 63
The Decomposition of the Elements 66
So-called Anomalies due to Form of the Atoms 71
Fusing Point Anomaly 72
Boiling Point Anomaly§ 75
The Form of the Atoms 77
The Atomic Weight of Pantogen 85

Sixteen full page Plates . . . . Plate 1 to 16

---

* First inductive Determination of the structure and form of the Element Atoms.

† Confirmation of the same.

‡ Second Confirmation of same.

§ Third Confirmation and Determination of the length of the atoms of the Sulphoids.

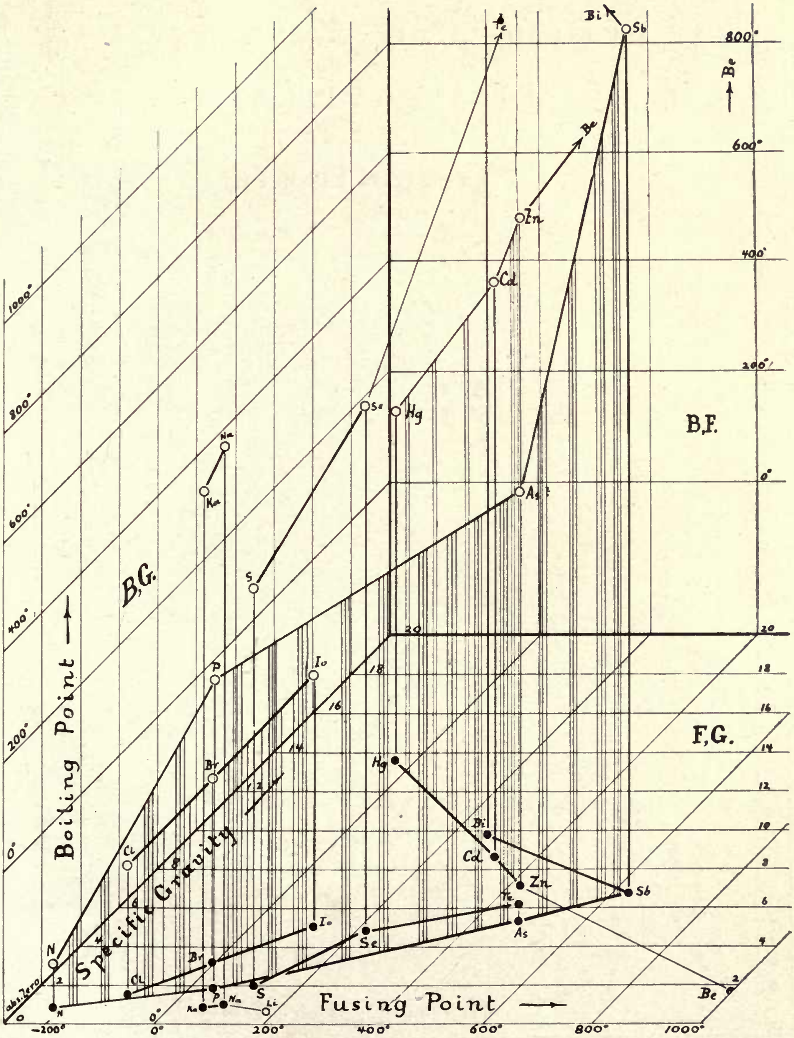

Boiling Point →
Specific Gravity
Fusing Point →
B,G.
B,F.
F,G.
1000°
800°
600°
400°
200°
0°
abs. Zero
0
-200°
0°
200°
400°
600°
800°
1000°
800°
600°
400°
200°
0°
20
18
16
14
12
10
8
6
4
2
0
2
4
6
8
12
14
16
18
20
N
Cl
Br
P
I
S
K
Na
Li
Se
Hg
Cd
Zn
Te
As
Sb
Bi
Be
Be →

PLATE I.

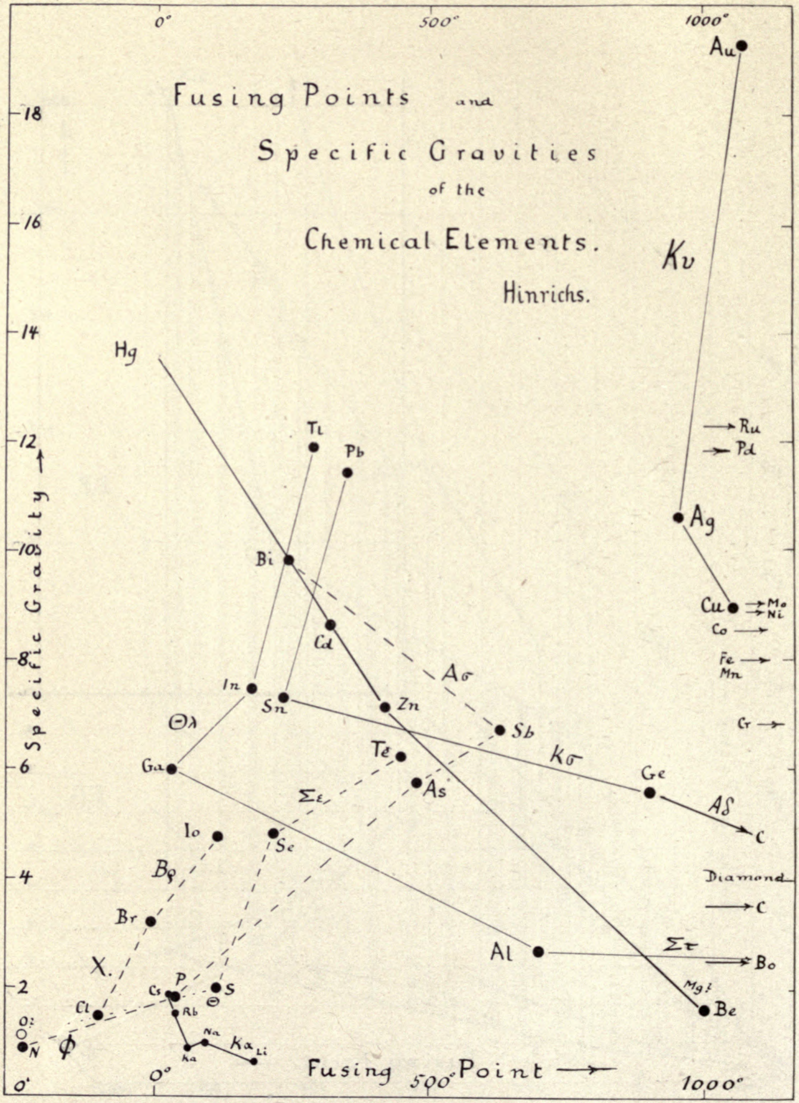

Fusing Points and Specific Gravities of the Chemical Elements.
Hinrichs.
0°
500°
1000°
18
16
14
12
10
8
6
4
2
0°
Specific Gravity →
Fusing Point →
Au
Kv
Hg
Tl
Pb
Ru
Pd
Ag
Bi
Cu
Mo
Ni
Co
Fe
Mn
Cd
Aσ
In
Sn
Zn
Sb
Cr
Θλ
Te
Kσ
Ga
As
Ge
Σε
AS
C
Io
Se
Bρ
Diamond
C
Br
Al
Στ
Bo
X.
P
Cs
S
Mg?
Be
Cl
Rb
Θ
O?
N
Φ
Na
Ka
Li
Ka

PLATE 2.

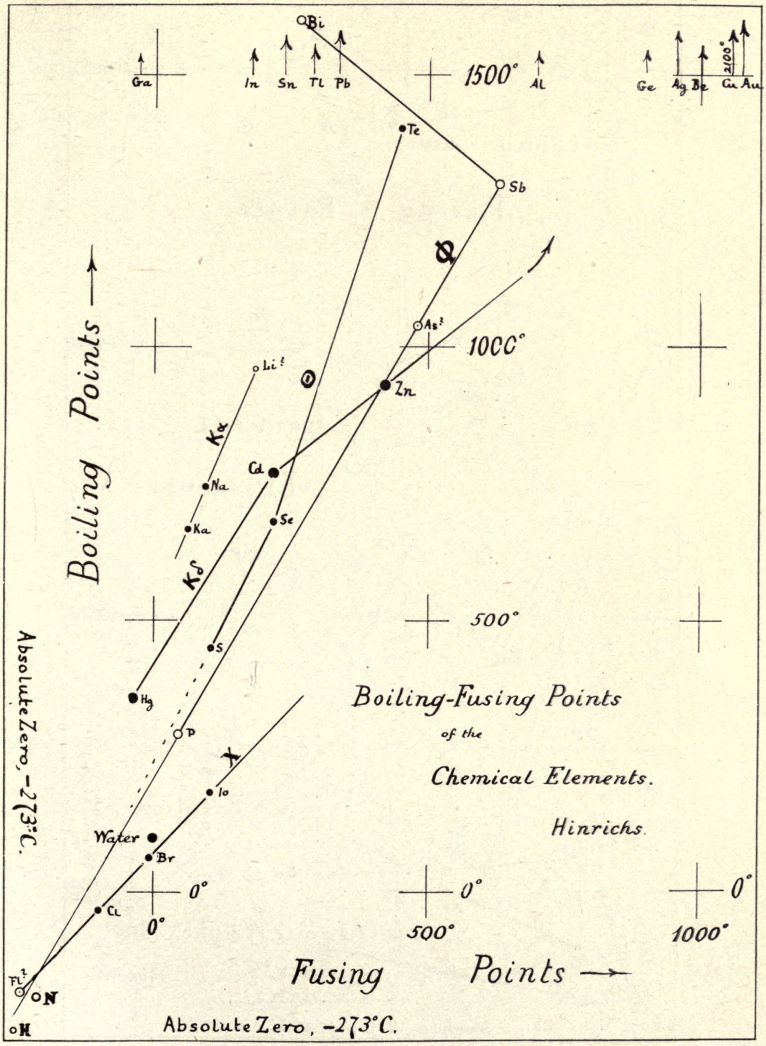

Boiling-Fusing Points
of the
Chemical Elements.
Hinrichs.
Boiling Points →
Fusing Points →
Absolute Zero, −273°C.
Absolute Zero, −273°C.
1500°
1000°
500°
0°
0°
0°
0°
500°
1000°
2100°
Ga
In
Sn
Tl
Pb
Bi
Al
Ge
Ag
Be
Cu
Au
Te
Sb
Φ
As?
Li?
Zn
Θ
Kα
Cd
Na
Ka
Se
Kδ
S
Hg
P
X
Io
Water
Br
Cl
Fl?
N
H

PLATE 3.

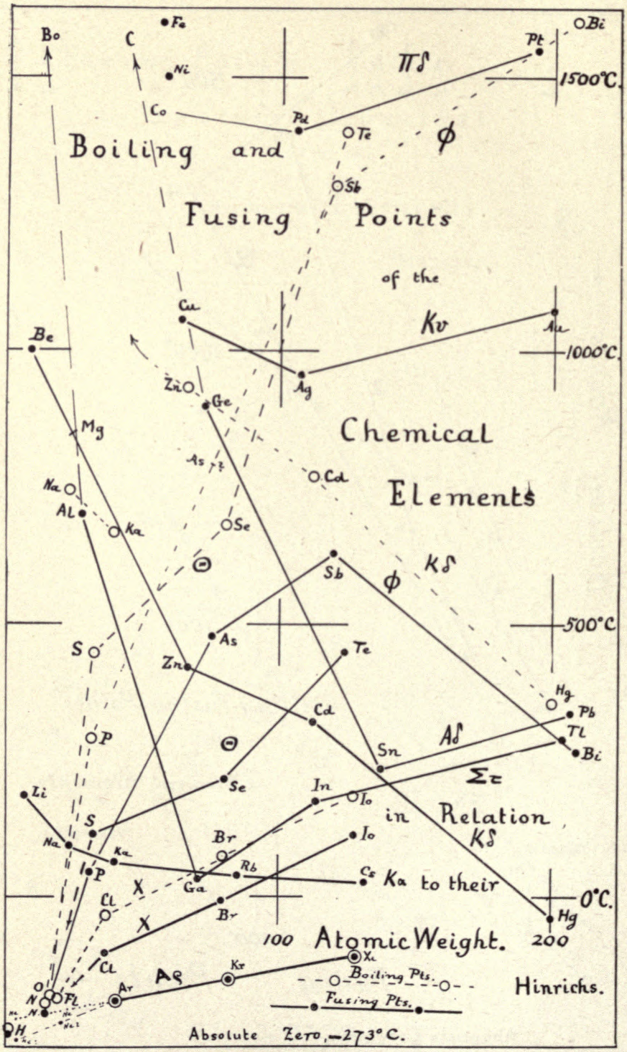

Boiling and Fusing Points of the Chemical Elements in Relation to their Atomic Weight.
Hinrichs.
1500°C.
1000°C.
500°C
0°C.
100
200
Absolute Zero, -273° C.
Boiling Pts.
Fusing Pts.
Bo
C
Fe
Ni
Co
Pd
Pt
Bi
Te
Sb
Cu
Ag
Au
Be
Mg
Na
Al
Ka
Zn
Ge
As ?
Cd
Se
S
P
Sb
As
Zn
Te
Cd
Sn
Hg
Pb
Tl
Bi
Li
Na
Ka
S
Se
In
Io
Br
Rb
Ga
Cs
Cl
Br
Io
Cl
Ar
Kr
Xe
O
N
Fl
N
H
πδ
φ
Kv
Kδ
φ
Θ
Θ
Aδ
Στ
Kδ
Ka
X
X
Aς

PLATE 4.

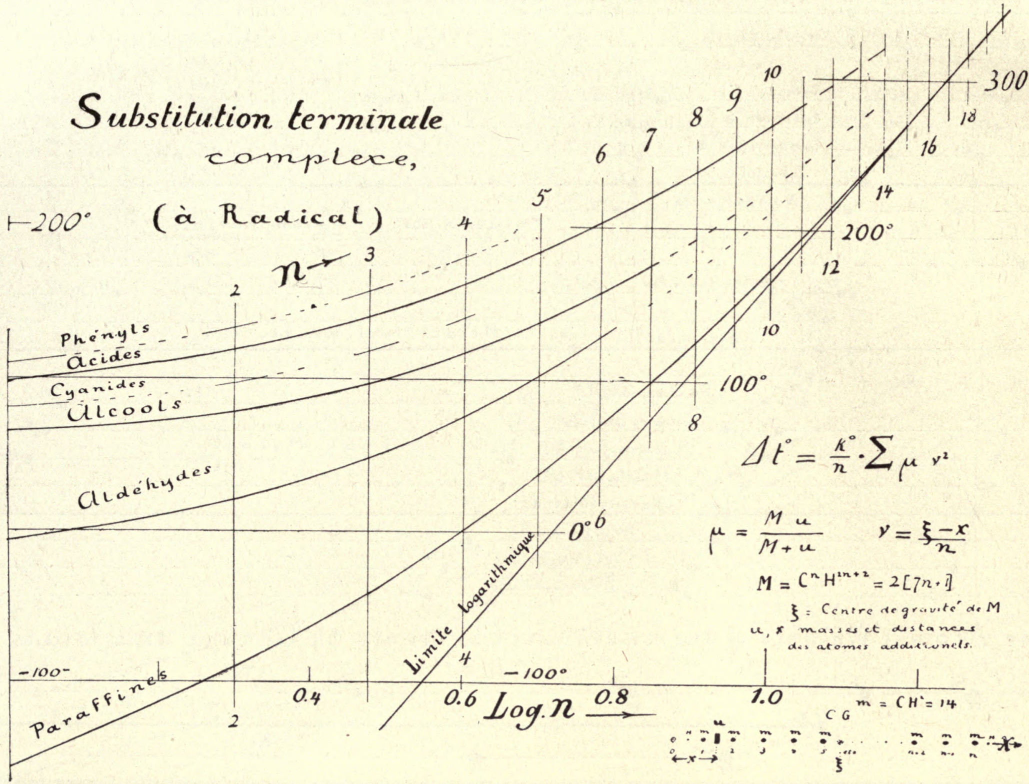
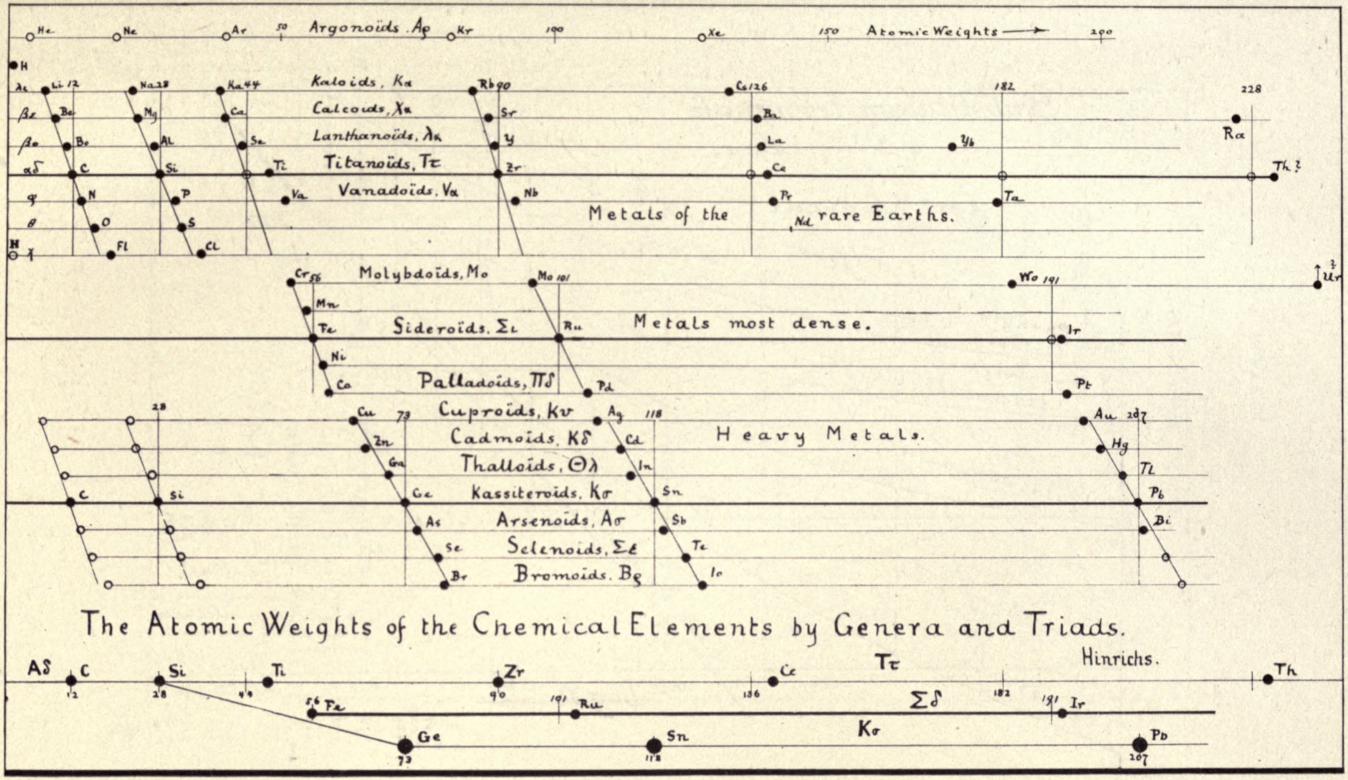

Substitution terminale complexe, (à Radical)
200°
n →
Phényls
Acides
Cyanides
Alcools
Aldéhydes
Paraffines
Limite logarithmique
-100-
-100°
0°
100°
200°
300°
0.4
0.6
0.8
1.0
Log. n →
2
3
4
5
6
7
8
9
10
12
14
16
18
Δt° = k°/n · Σ μ ν²
μ = Mu/(M+u)
ν = (ξ − x)/n
M = CⁿH²ⁿ⁺² = 2[7n+1]
ξ : Centre de gravité de M
u, x masses et distances des atomes additionnels.
CG
m = CH² = 14

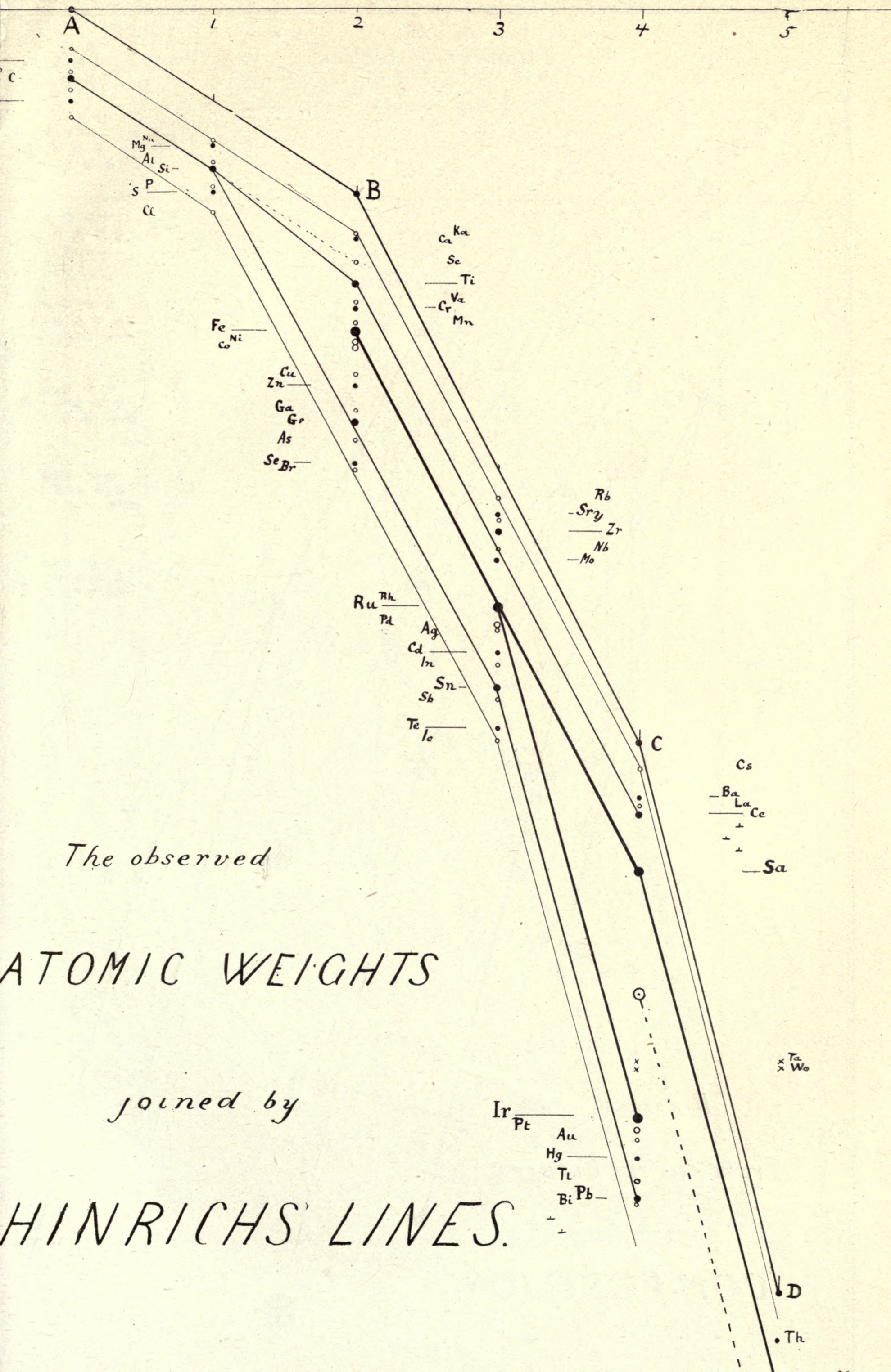
PLATE 5.



The Atomic Weights of the Chemical Elements by Genera and Triads.

Hinrichs.

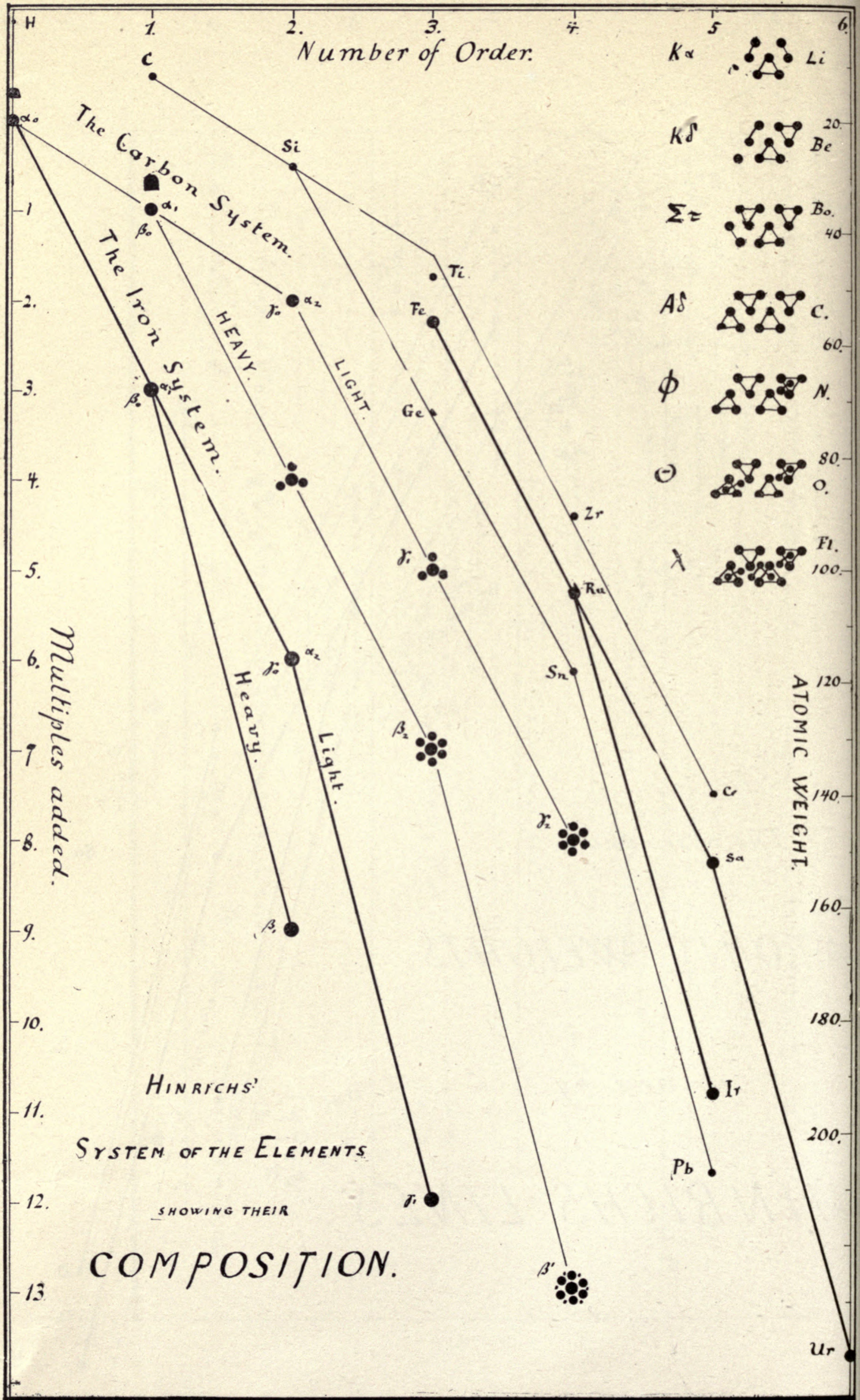
PLATE 6.


The observed

ATOMIC WEIGHTS

joined by

HINRICHS' LINES.



HINRICHS'

SYSTEM OF THE ELEMENTS

SHOWING THEIR

COMPOSITION.

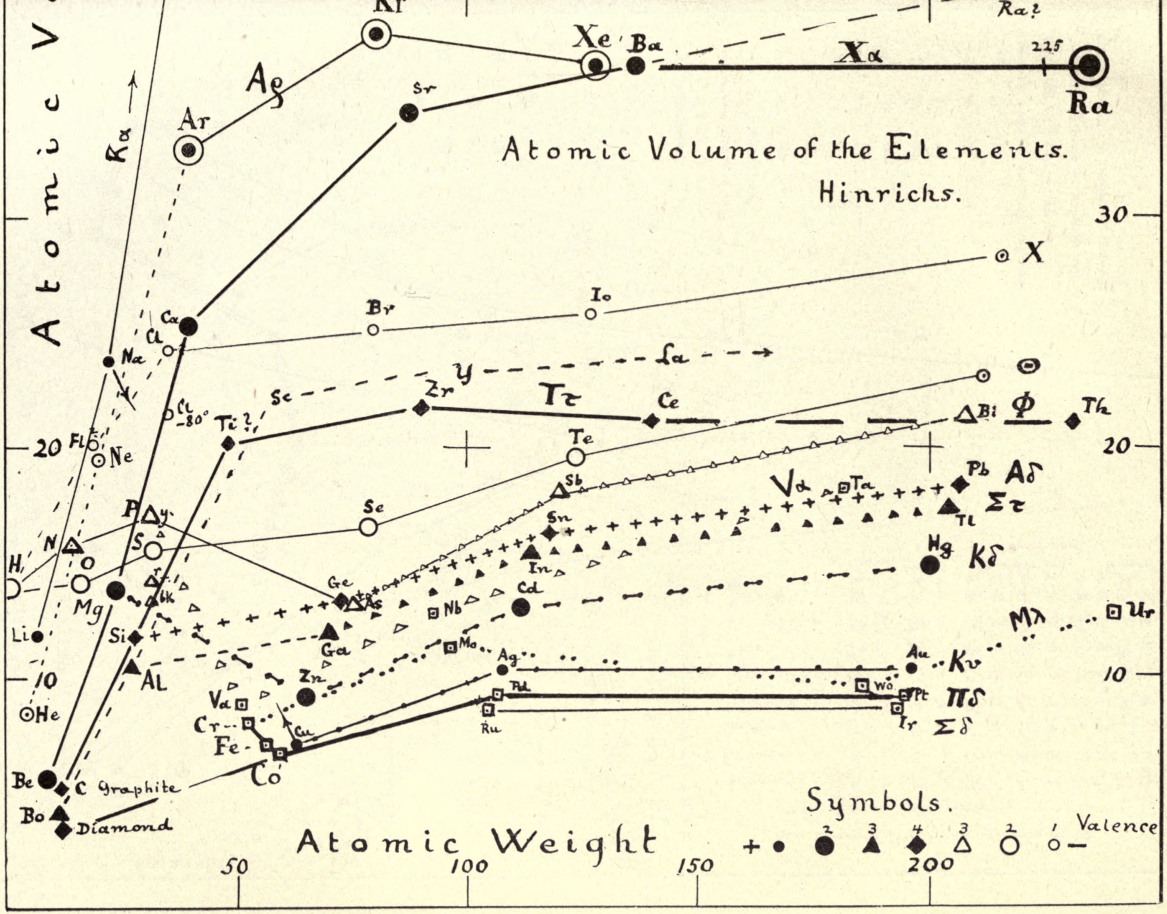
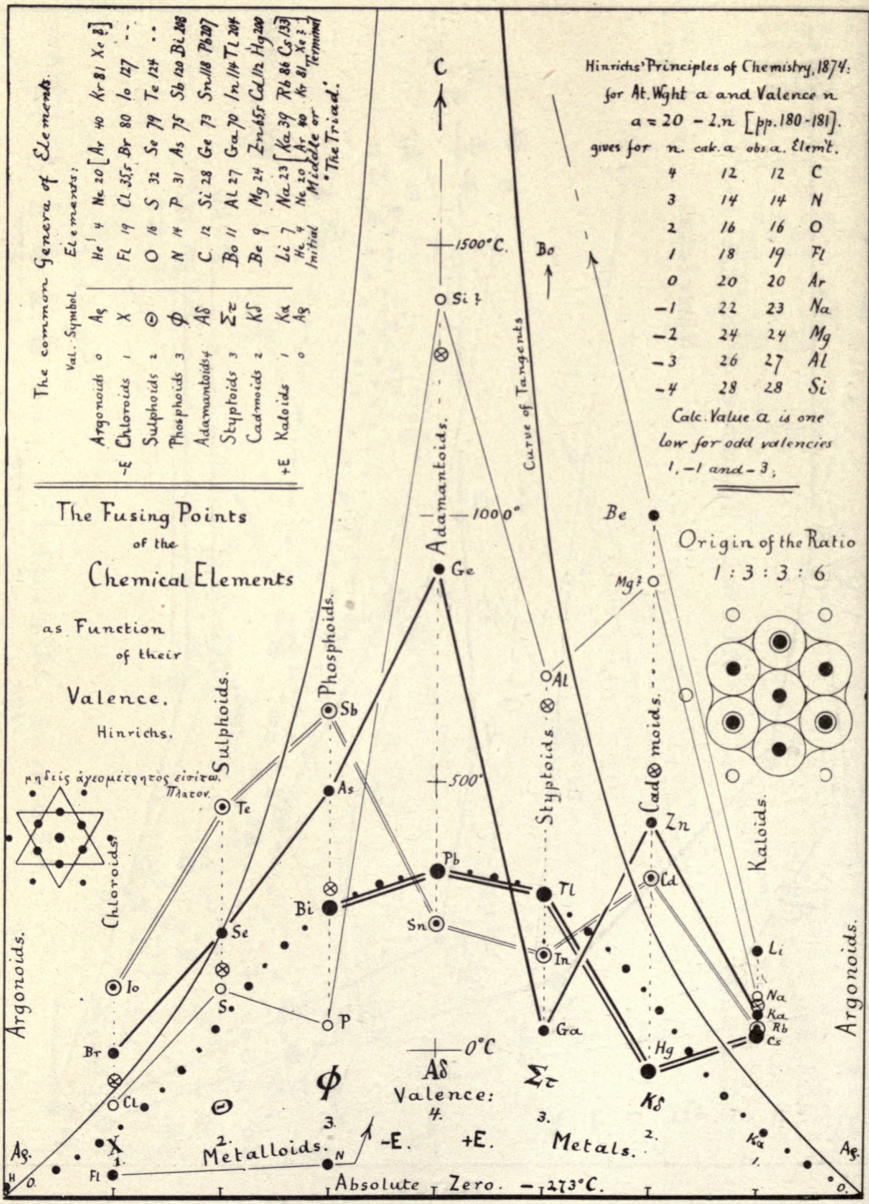

Atomic Volume of the Elements.
Hinrichs.
Atomic Weight
Atomic V
50
100
150
200
10
20
30
Symbols.
Valence
+ • 2 ● 3 ▲ 4 ◆ 3 △ 2 ○ 1 ○ —
Kr
Xe
Ba
Xα
225
Ra
Ra?
Aϱ
Ar
Sr
Rα
Ca
Na
Cl
Cl -80°
Br
Io
X
Sc
Zr
Y
La
Tτ
Ce
Ti ?
Θ
Φ
Bi
Th
Fl
Ne
Te
Se
Sb
Vα
Ta
Pb
Aδ
Στ
Tl
Sn
In
Hg
Kδ
P
N
O
H
S
Mg
Li
Si
Ge
As
Nb
Cd
Ga
Mo
Mλ
Ur
Al
Ag
Au
Kν
Zn
Vd
Cr
Fe
Co
Cu
Pd
Wo
Pt
Ru
Ir
Πδ
Σδ
He
Be
C
Graphite
Bo
Diamond

PLATE 9.



The common Genera of Elements.

		Val.	Symbol	Elements:				
	Argonoids	0	Aę	He 4	Ne 20	[Ar 40	Kr 81	Xe ?]
−E	Chloroids	1	X	Fl 19	Cl 35.5	Br 80	Io 127	..
	Sulphoids	2	⊙	O 16	S 32	Se 79	Te 124	..
	Phosphoids	3	Φ	N 14	P 31	As 75	Sb 120	Bi 208
	Adamantoids	4	AΔ	C 12	Si 28	Ge 73	Sn 118	Pb 207
	Styptoids	3	Στ	Bo 11	Al 27	Ga 70	In 114	Tl 204
	Cadmoids	2	KΔ	Be 9	Mg 24	Zn 65.5	Cd 112	Hg 200
+E	Kaloids	1	Ka	Li 7	Na 23	[Ka 39	Rb 86	Cs 133]
		0	Aę	He 4	Ne 20	[Ar 40	Kr 81	Xe ?]
				Initial		Middle or "The Triad."		Terminal

Hinrichs' Principles of Chemistry, 1874:
for At. Wght a and Valence n
$a = 20 - 2.n$ [pp. 180-181].

gives for	n.	calc. a	obs. a.	Elem't.
	4	12	12	C
	3	14	14	N
	2	16	16	O
	1	18	19	Fl
	0	20	20	Ar
	−1	22	23	Na
	−2	24	24	Mg
	−3	26	27	Al
	−4	28	28	Si

Calc. Value a is one low for odd valencies 1, −1 and −3;

PLATE 10.

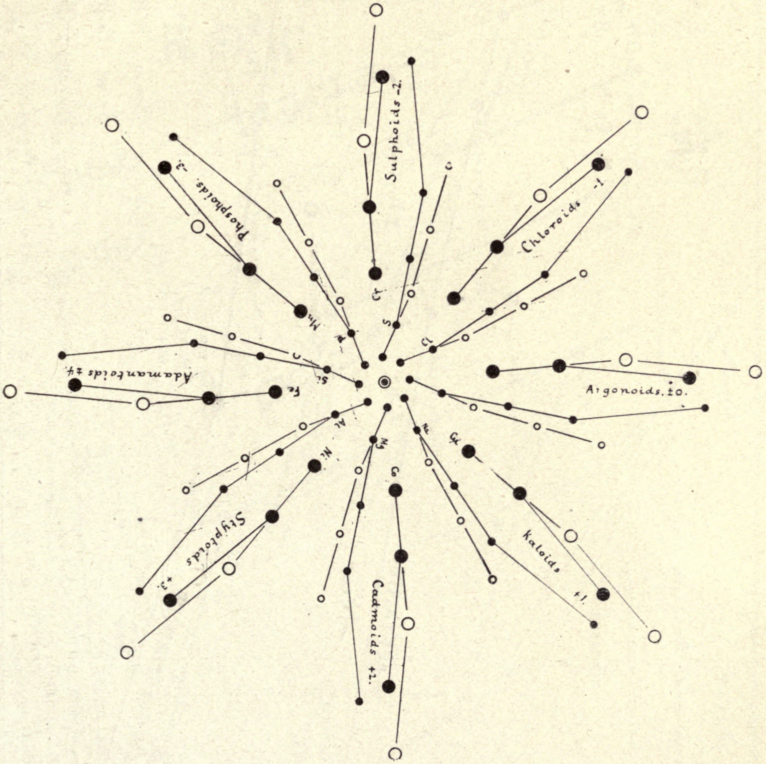

Sulphoids -2.
C
Cr
S
Chloroids -1
Cl
Argonoids. ±0.
Na
Cu
Kaloids +1.
Co
Mg
Cadmoids +2.
Ni
Al
Styptoids +3.
Fe
Si
Adamantoids ±4
P
Mn
Phosphoids -3

PLATE II.

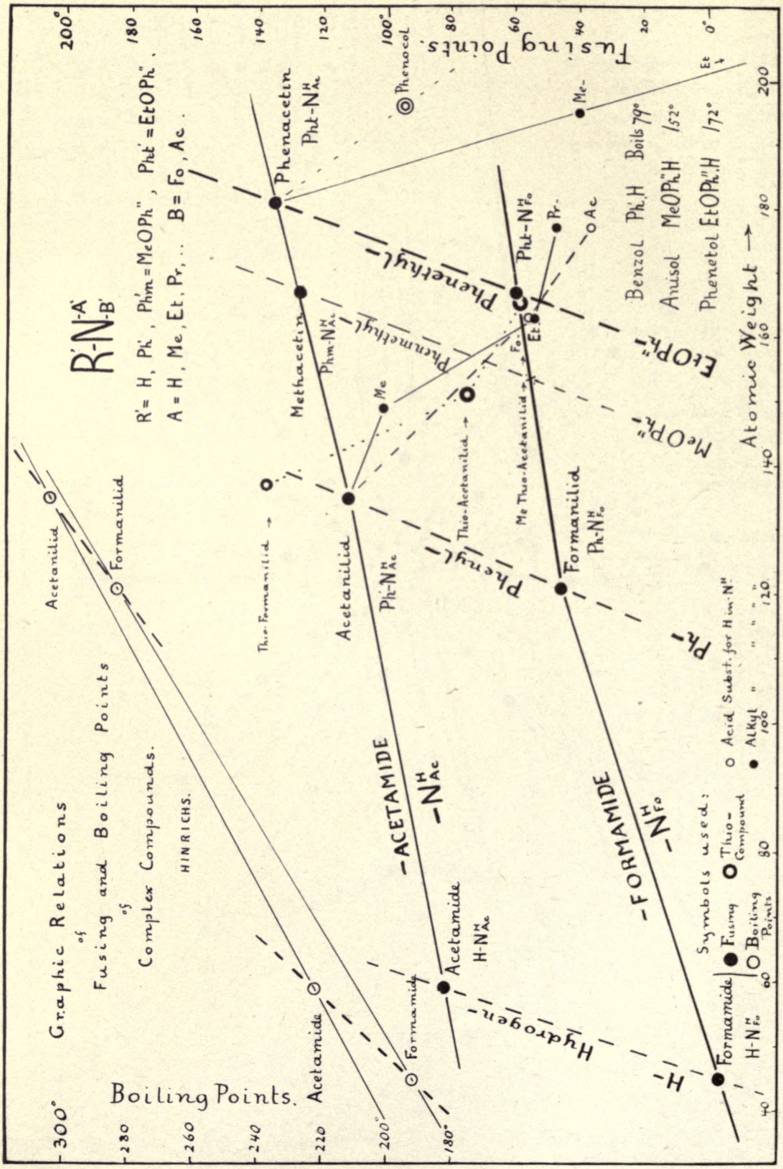

Graphic Relations of Fusing and Boiling Points of Complex Compounds.
HINRICHS.
R'-N-A' / B'
R' = H, Ph', Ph'm = MeOPh'', Ph't' = EtOPh''.
A = H, Me, Et, Pr, .. B = Fo, Ac.
Boiling Points.
Fusing Points.
Atomic Weight →
300°
280
260
240
220
200°
180°
200°
180
160
140
120
100°
80
60
40
20
0°
40
60
80
100
120
140
160
180
200
Acetamide
Formamide
Acetanilid
Formanilid
-ACETAMIDE -N^H_Ac
-FORMAMIDE -N^H_Fo
Acetamide H-N^H_Ac
Formamide H-N^H_Fo
Hydrogen-
H-
Acetanilid Ph'-N^H_Ac
Formanilid Ph'-N^H_Fo
Phenyl-
Ph'-
Methacetin Ph'm-N^H_Ac
Phenmethyl-
MeOPh''-
Phenacetin Ph't-N^H_Ac
Pht-N^H_Fo
Phenethyl-
EtOPh''-
Thio-Formanilid →
Thio-Acetanilid →
Me Thio-Acetanilid →
Me
Me-
Et
Et-
Pr-
o Ac
Fo
Phenocol
Benzol Ph'.H Boils 79°
Anisol MeOPh''H 152°
Phenetol EtOPh''H 172°
Symbols used:
● Fusing
○ Boiling Points
○ Thio-Compound
○ Acid Subst. for H in N^H
● Alkyl " " "

PLATE 12.

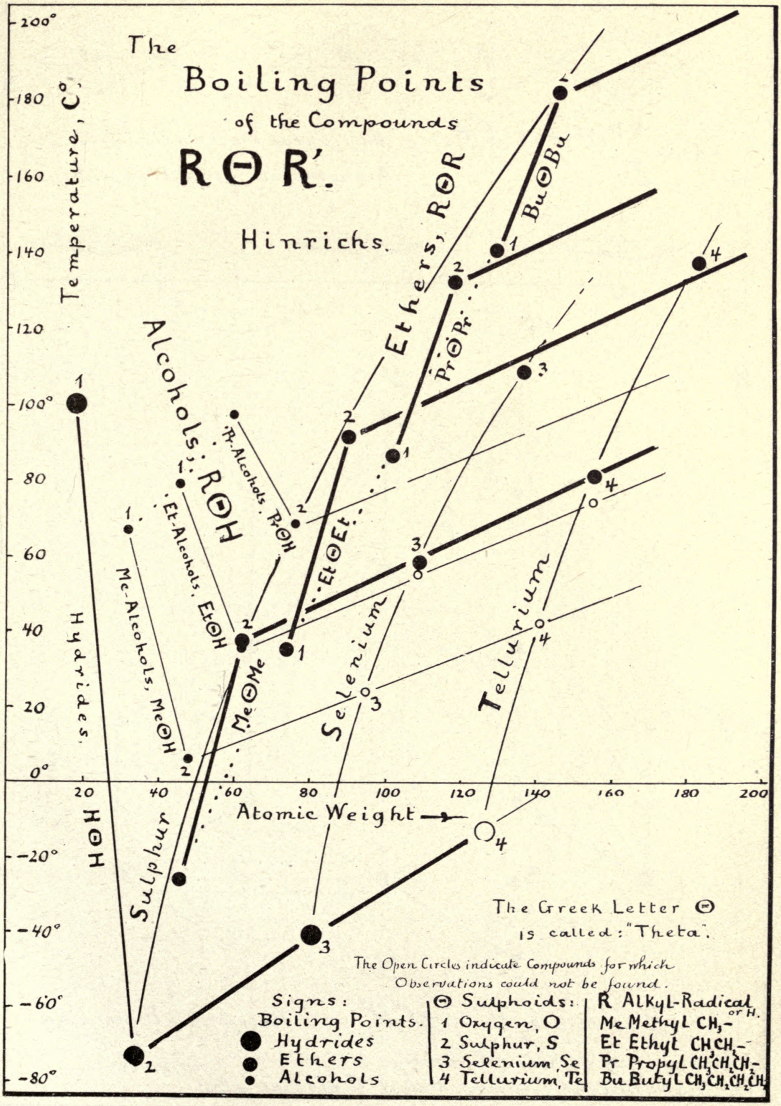
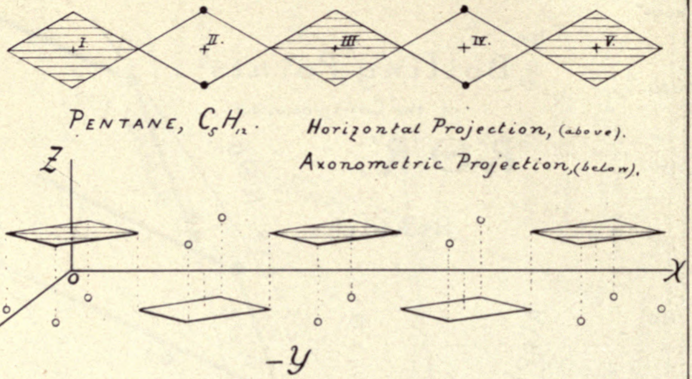
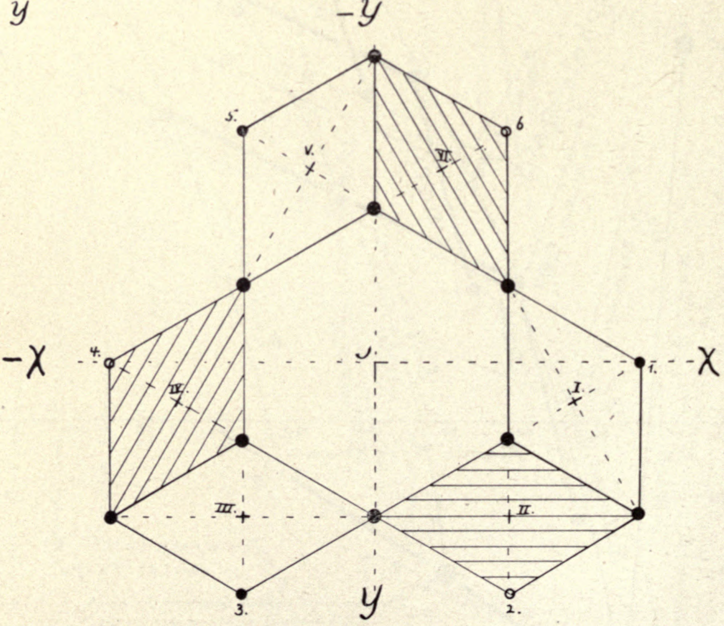

The Boiling Points of the Compounds RΘR'.
Hinrichs.
Temperature, C°.
200°
180
160
140
120
100°
80
60
40
20
0°
-20°
-40°
-60°
-80°
20
40
60
80
100
120
140
160
180
200
Atomic Weight
Hydrides.
HΘH
Alcohols; RΘH
Me-Alcohols, MeΘH
Et-Alcohols, EtΘH
Pr-Alcohols. PrΘH
Ethers, RΘR
MeΘMe
EtΘEt
PrΘPr
BuΘBu
Sulphur
Selenium
Tellurium
1
2
3
4
The Greek Letter Θ is called: "Theta".
The Open Circles indicate Compounds for which Observations could not be found.
Signs: Boiling Points.
Hydrides
Ethers
Alcohols
Θ Sulphoids:
1 Oxygen, O
2 Sulphur, S
3 Selenium, Se
4 Tellurium, Te
R Alkyl-Radical or H.
Me Methyl CH3-
Et Ethyl CH3CH2-
Pr Propyl CH3CH2CH2-
Bu Butyl CH3CH2CH2CH2-

PLATE 13.



PENTANE, C_5H_{12}. Horizontal Projection, (above).
Axonometric Projection, (below).



BENZOL, C_6H_6 or $3C_2H_2$. Horizontal Projection.

Unit of Length = Side of C-atom.
Diagonals of C-atom: 1 and $\sqrt{3} = 1.73205$ or 1.732.

HINRICHS.

PLATE 14.

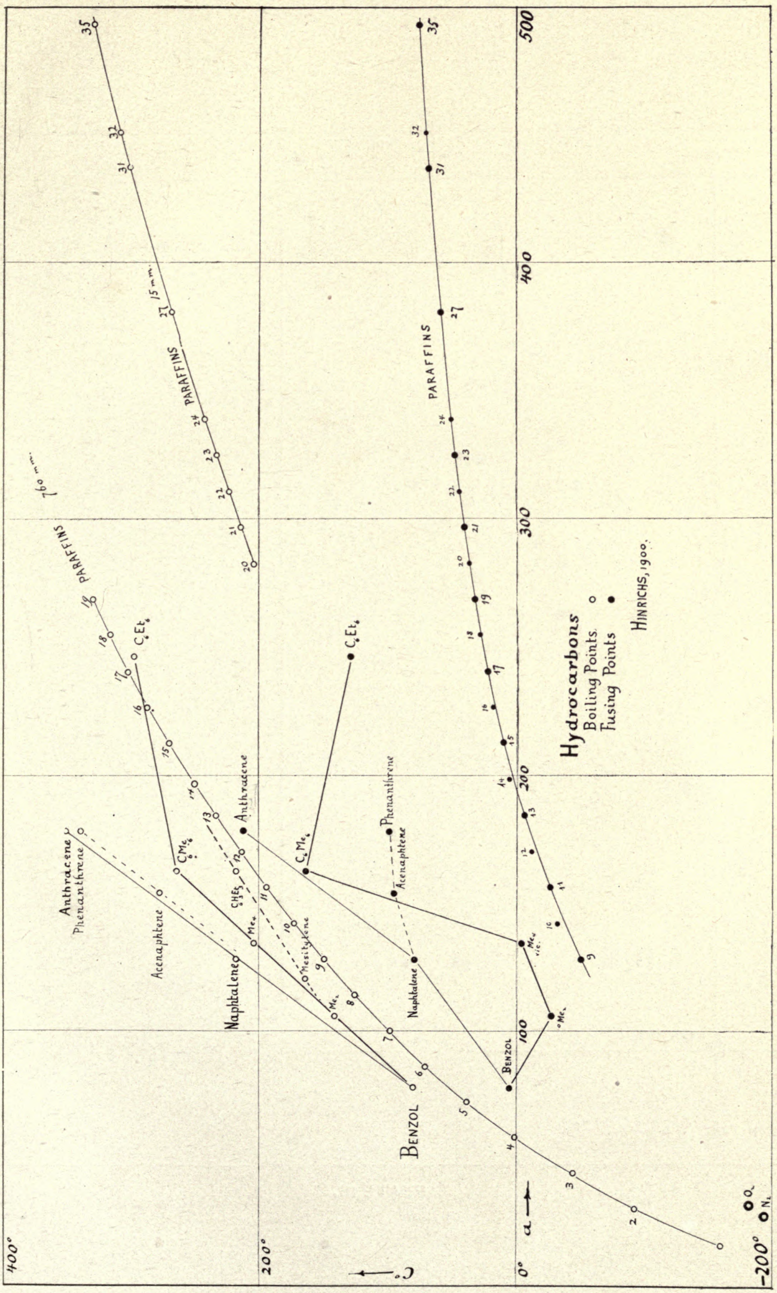

Hydrocarbons
Boiling Points ○
Fusing Points ●
HINRICHS, 1900.
PARAFFINS
760 mm.
15 mm.
BENZOL
Naphtalene
Acenaphtene
Anthracene
Phenanthrene
Mesitylene
C_6Me_6
C_6Et_6
$C_6H_3Et_3$
Me4
o Me4
Me4 vic.
O_2
N_2
a →
c° ←
400°
200°
0°
-200°
0
100
200
300
400
500
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
27
31
32
35

PLATE 15.

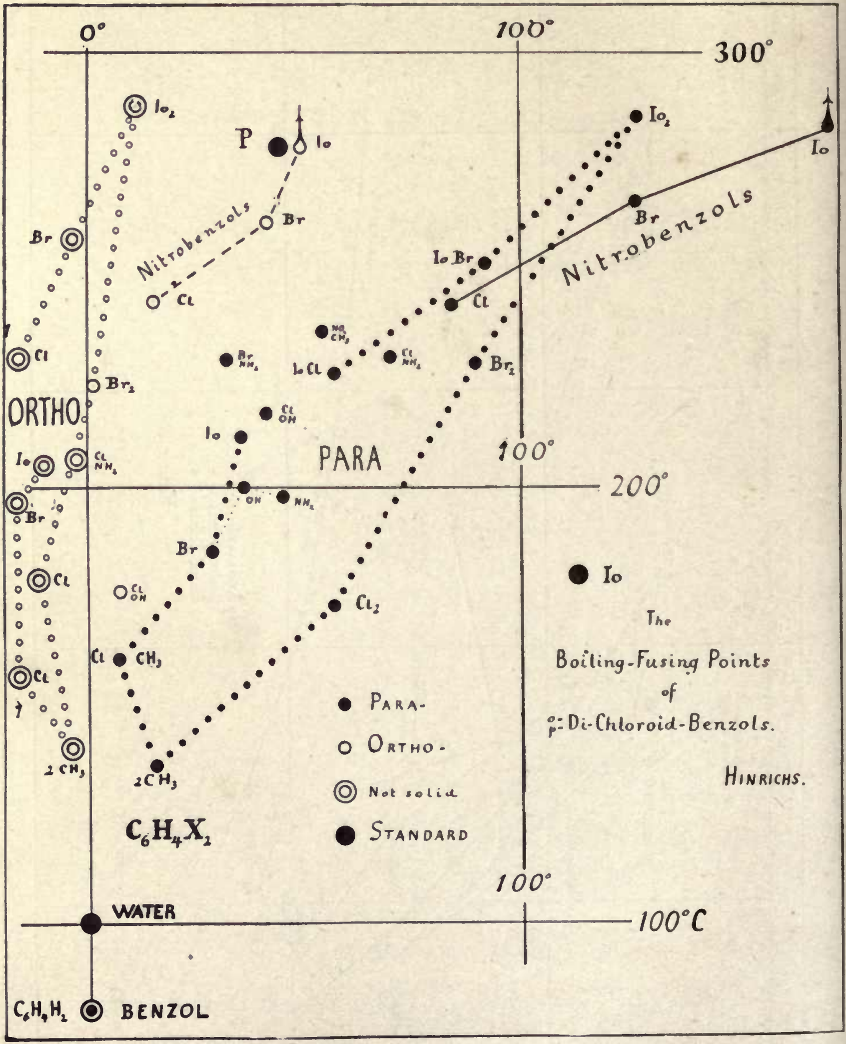

0°
100°
300°
200°
100°
100°C
P
Io
Io₂
Br
Cl
Br₂
ORTHO
Io
Cl NH₂
Br
Cl
Cl
2 CH₃
Nitrobenzols
Cl
Br
NO₂ CH₃
Br NH₂
Io Cl
Cl NH₂
Io Br
Cl
Br₂
Cl OH
Io
PARA
OH
NH₂
Br
Cl OH
Cl₂
Cl CH₃
2 CH₃
Nitrobenzols
Br
Io
Io₂
Io
Para-
Ortho-
Not solid
Standard
C₆H₄X₂
WATER
C₆H₄H₂
BENZOL
The
Boiling-Fusing Points
of
o/p-Di-Chloroid-Benzols.
Hinrichs.

PLATE 16.

THE

ABSOLUTE ATOMIC WEIGHTS

OF THE

CHEMICAL ELEMENTS

ESTABLISHED UPON THE ANALYSES
.... OF THE ....

CHEMISTS OF THE NINETEENTH CENTURY

AND DEMONSTRATING THE

UNITY OF MATTER;

PRESENTED IN SIMPLE LANGUAGE
.... TO THE ....

GENERAL SCIENTIFIC PUBLIC,

—BY—

GUSTAVUS DETLEF HINRICHS, M. D., LL.D.,

Honorary and Corresponding Member of Scientific Societies in Austria, England, France, Germany and the United States; Professor of Chemistry in the St. Louis College of Pharmacy.

WITH A PORTRAIT OF BERZELIUS AND THREE PLATES.

ST. LOUIS, MO., U. S.
CARL GUSTAV HINRICHS, PUBLISHER.
1901.

Recent Works by Dr. Gustavus D. Hinrichs:

The True Atomic Weights
of the Chemical Elements, and the Unity of Matter,
pp. XVI, 256, 8vo, 7 plates, many illustrations; fine paper, cloth binding. Price, $2.00.

"I have read it with the greatest satisfaction, and find your critique well founded, as also your admiration for those determinations which till now have been unjustly depreciated."—Charles Friedel.

"On many points I agree with you, especially in your critical examinations of the determinations of Stas.—A. Cornu.

Introduction to General Chemistry.

A Graded Course of One Hundred Lectures, with an Atlas of Eighty Plates, representing Chemists, Institutions, Prime Materials, Crystals, Diagrams and Apparatus.
400 pages, octavo; bound in cloth; price $4.00.

This work is the best illustrated and most carefully graded course in Chemistry, leading up from the oldest chemical practice of the Ancients and the Alchemists, through the discoveries of the last two centuries to the highest problems of the science in chemical synthesis of organic compounds, their atomic structure, chemical mechanics, and the unity of matter.

The common things, being also technically and economically the most valuable, form the starting point, both in the mineral and organic division of this work; the seven great metals known to the Ancients, and the staples of Agriculture, are the material basis of all chemical science.

Order these books through your bookseller. They are kept in stock by Lemcke & Buechner, New York and Leipzig, also by H. Grevel & Co., London, England, and by H. Le Soudier, Paris, France.

These books will be sent prepaid by registered mail to any address within the Postal Union on the receipt of price (Postal Money Order), by addressing exactly as here stated:

Carl G. Hinrichs, Publisher,
4106 Shenandoah Ave.,
St. Louis, Mo.
America.

General Chemistry out of print; new edition in preparation.