

## Clemens Alexander Winkler (1838-1904) – the Outstanding German Chemist of the Second Half of the XIX Century

### *Clemens Alexander Winkler (1838-1904) - el químico alemán destacado de la segunda mitad del siglo XIX*

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#### ABSTRACT

Clemens Alexander Winkler (1838-1904) was one of the prominent chemists of the second half of the XIX century. He was the founder of technical gas-analysis. He made major contributions both to pure and applied chemistry. He also developed a contact method for the production of sulfuric anhydride (sulfur trioxide) and discovered Germanium. The purpose of this paper is to familiarize readers with the important events in the life of Winkler and his research activities, in particular with his selected publications as well as with his writing activities, in particular with his books. In addition, literature on his correspondence with some great chemists is given.

**Keywords:** C. A. Winkler, Industrial method for producing sulfuric anhydride, Analysis of technical gases, Germanium, Germany – XIX century.

#### RESUMEN

Clemens Alexander Winkler (1838-1904) fue uno de los químicos destacados de la segunda mitad del siglo XIX. Fue el fundador del análisis técnico de gases. Hizo importantes contribuciones tanto a la química pura como a la aplicada. También desarrolló un método de contacto para la producción de anhídrido sulfúrico (trioxido de azufre) y descubrió el germanio. El propósito de este artículo es familiarizar a los lectores con los acontecimientos importantes de la vida de Winkler y sus actividades de investigación, en particular con sus publicaciones seleccionadas, así como con sus actividades de escritura, en particular con sus libros. Además, se proporciona literatura sobre su correspondencia con algunos grandes químicos.

**Palabras claves:** C. A. Winkler, Método industrial para producir anhídrido sulfúrico, Análisis de gases técnicos, Germanio, Alemania - siglo XIX

*Die Welt der chemischen Vorgänge gleicht einer Bühne, auf welcher sich in unablässiger Aufeinanderfolge Scene um Scene abspielt. Die handelnden Personen auf ihr sind die Elemente (The world of chemical processes is like a stage, on which scene after scene is played out in incessant succession. The people acting on it are the elements).*

Clemens Winkler, 1897b, p. 13.

## INTRODUCTION

### *The important events in the Winkler's life*

Clemens Alexander Winkler (Figure 1) known simply as Clemens Winkler was called “the outstanding inorganic chemist of his time” (Smith, 1949, p. 256). He “made brilliant contributions both to pure and applied chemistry” (Weeks, 1956, p. 689). One hundred and seventeen years have passed since his death, but in that time little has appeared in the literature about this very interesting man. Among his most important scientific achievements, the American chemist Henry Monmouth Smith (1868-1950) mentioned in his 1949 book:

Prepared metallic cobalt in quantity. Determined the atomic weight of indium. ... Introduced the term “normal weight” in volumetric analysis and the test for carbon monoxide by palladium chloride; determined sodium hydroxide in the presence of alkali carbonates. ... After working day and night for several months he discovered ... a new element which he named germanium. ... Reduced oxides with magnesium, and prepared hydrides of metals. Developed the Contact Process for sulfuric acid ... Improved gas analysis and invented the three-way stopcock (p. 256).

Clemens Winkler was born in Freiberg (Kingdom of Saxony) on December, 26, 1838, and he was the son of Kurt Alexander Winkler (1794-1862), a chemist and metallurgist who studied under the Swedish chemist Jöns Jacob Berzelius (1779-1848), and his wife Elmonde Antonie, née Schramm (1810-1897) (Winkler, 1954, p. 11).

In April 1851 he went to the *Gymnasium* in Freiberg. From 1852 to 1853, he attended the *Realschule* in Dresden. In the years 1855-1856, he continued his education at the *Gewerbschule* in Chemnitz (Winkler, 1954, pp. 14-15). In 1857, he began his three-year (1857-1859) studies at the *Königlich Sächsische Bergakademie* (Royal Saxon Mining Academy) in Freiberg (Haustein, 2011, p. 141; Weinert, 2020, p. 9; Prokop, 1954, p. 94). At this academy, he became interested in chemistry, especially mineral chemistry, which he dealt under the mineralogist August Breithaupt (1791-1973) (Anonymous, 1904, p. 900).

On October 1, 1859, he was employed as *Akzessist* at the *Königlich Sächsische Blaufarbenwerk Oberschlema* and on October 1, 1862, he began working as a metallurgical chemist at *Privatblaufarbenwerkes Pfannenstiel* (Pfannenstiel Private Blue Dye plant) at Aue (Haustein, 2011, p. 141; Prokop, 1954, p. 94).

On January 8, 1863, he married Minna Laura, née Pohl (1843-1891) (Papperitz, 1904, p. 5; Prokop, 1954, p. 94; Winkler, 1954, p. 24). The spouses had six children: four sons and two daughters (Brunck, 1906, p. 4498).

In 1864, he presented two of his publications as a dissertation at the University of Leipzig: *Ueber Siliciumlegirungen und Siliciumarsenmetalle* (About alloys of silicon and silicon/arsenic metal compounds) (Winkler, 1864a) and *Die maassanalytische Bestimmung des Wassers in organischen Flüssigkeiten* (The Analytical Determination of Water in Organic Liquids) (Winkler, 1864b). On February 7, 1864, he received his Ph.D. (Haustein, 2011, p. 141; Prokop, 1954, p. 94).

On September 1, 1873, he was appointed Professor of Inorganic Chemistry at the Mining Academy in Freiberg. He was the successor of Theodor Scheerer (1813-1875).

Leroy Wiley McCay studied in Germany for four years, first in Freiberg in 1879. There he attended lectures by Winkler, who he describes in his article (1930) as follows: He was in his early forties, of moderate height, thick-set, wore a short dark beard ... He had an attractive face, an engaging smile, and his voice, while low, had a peculiar penetrating power. ... His lectures on general as well as applied chemistry were extraordinarily gripping, for he had the power to communicate to his hearers the

enthusiasm for the science which he himself possessed. He made his experiments himself and very rarely called upon an assistant for help. ... His German was simple, straightforward ... He knew little French and less English, but he was a master of his own language. ... His good nature, his winning manner, his generosity, his bonhomie, and his keen social instinct captured the love of all, students, colleagues, and fellow citizens. ... In my day he was the most popular man in Freiberg (pp. 1086-1087).

On September 2, 1896, after Theodor Richter's (1824-1898) resignation, Winkler was appointed Director of the Mining Academy, which he headed for three years, until to autumn 1899 (Brunck, 1906, p. 4515; Prokop, 1954, p. 95).

On November 30, 1901, he was appointed to the editorial board of the *Zeitschrift für angewandte Chemie*. In the summer of 1902, due to health problems, he resigned from work at the Academy and on August 12 he moved to Dresden (Prokop, 1954, p. 96).

On October 8, 1904, he died of lung cancer (Brunck, 1906, p. 4516). Erwin Papperitz (1904) wrote about his funeral as follows:

On October 11th, Winkler was solemnly buried to eternal rest in the Trinitatisfriedhofe zu Dresden [Trinity Cemetery in Dresden] amid moving manifestations of mourning on the part of all those who had learned to love and respect him. The great scholar, the loyal advisor and friend of the miners and huts, has "done his last shift". Now the eternal light of truth shines for him, which he had so eagerly investigated in life (p.12).

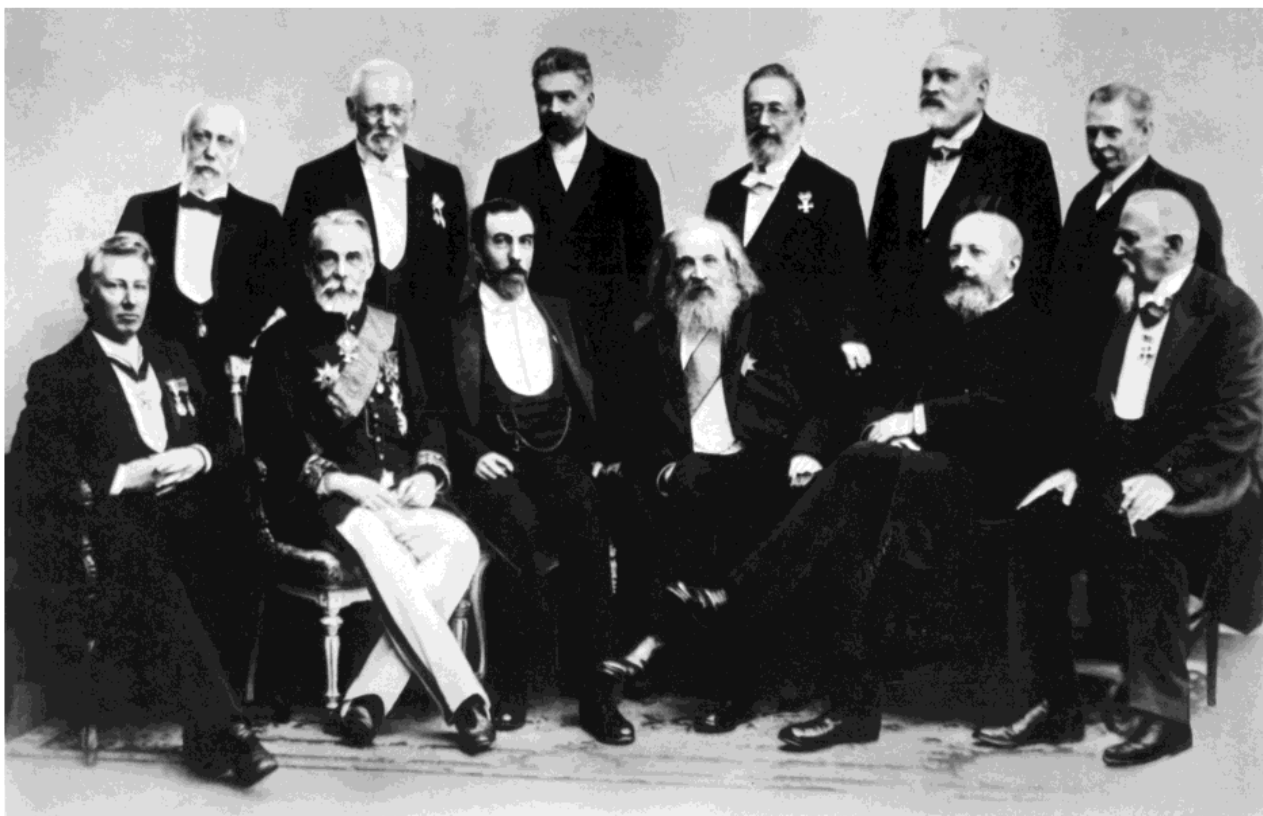


*Fig. 1. C. Winkler (1838-1904) ("Clemens Winkler als", 1875).*

### **Winkler's participation in the scientific celebration in Berlin**

On March 19-20, 1900, Winkler took part in the Berlin conference devoted to the

200th Anniversary of the *Königlich Preußischen Akademie der Wissenschaften* (Royal Prussian Academy of Sciences). Figure 2 is a photography made during this celebration (“200th Anniversary of Berlin”, 1900). The American biochemists Benjamin Harrow (1888-1970) inserted this photo on the one of first pages of his book entitled *Eminent Chemists of Our Time*. He also wrote that it “showing several eminent chemists was taken at one of the international scientific gatherings” (Harrow, 1920, p. 8).



*Fig. 2. Winkler with the group of the prominent chemists (“200th Anniversary of Berlin”, 1900)*

Photograph was published by Harrow thanks to the kindness of the Dutch chemist Ernst Julius Cohen (1869-1944) (Donnan, 1948). Winkler is second from the right in the second row; to his left is the British chemist and historian of chemistry Sir Thomas Edward Thorpe (1845-1925) (Tutton, 1925; Szejnberg, 2021a). To his right are the German chemist Hans Heinrich Landolt (1831-1910) (Oesper, 1945), the Finnish chemist and historian of chemistry Edvard Hjelt (1855-1921) (Kauffman & NiiNistö, 1998), the Danish chemist Sophus Mads Jørgensen (1837-1914) (Kauffman, 1992), and the German chemist and historian of chemistry Albert Ladenburg (1842-1911) (Szejnberg, 2021b). Seated from the left to right in the front row are van’t Hoff, the Russian - German chemist Friedrich Konrad Beilstein (1838-1906) (Szejnberg, 2021c), the British chemist Sir William Ramsay (1852-1916), who found neon, argon, krypton, and xenon in air and was awarded the Nobel Prize in Chemistry in 1904 (Tilden, 1918), the Russian chemist Dmitri Ivanovich Mendeleev, who discovered the Periodic Law in 1871 (Boeck & Zott, 2007; Szejnberg, 2018), the German chemist Adolf von Baeyer (1835-1917), who received the Nobel Prize in Chemistry in 1905 (Baeyer, Villiger, Hottenroth, & Hallensleben, 1905),

and the Italian chemist Alfonso Cossa (1833-1902) (Kauffman & Molayem, 1990).

### Winkler's works

The list of Winkler's works includes one hundred and thirty papers published over a 45-year period, from 1859 to 1904. There are the articles published in Germany, among other in the *Berichte der deutschen chemischen Gesellschaft*, *Zeitschrift für analytische Chemie* and *Journal für Praktische Chemie*. Between 1859-1900, he published 32 articles in the field of analytical chemistry. Forty-seven of his papers in the field of general chemistry and inorganic chemistry appeared in print in the years 1863-1904. In 1869-1900, he published 33 technological articles. The nine papers that were published in the years 1872-1900 were devoted to chemical apparatus. Nine of his articles from 1875-1902 dealt with a variety of topics (Lissner, 1954, pp. 63-68).

Winkler's first work concerned the composition of the condurrite (Winkler, 1859). In the next eight years he focused his research on analytical as well as general and inorganic chemistry. In one of the articles from 1864 he described Thompson's separation method for cobalt and nickel (Winkler, 1864c). Two of his other papers in the same year dealt with cobaltic acid (Winkler, 1864d; Winkler, 1864e). In the years 1865-1867, indium became the object of his research interests (Winkler, 1865; Winkler, 1867a).

In 1875, he developed an industrial method for the production of sulfuric anhydride, which marked the beginning of the contact method for the production of sulfuric acid (Winkler, 1875a). On June 7 and 8, 1900, he participated in the general meeting of the Association of German Chemists in Hanover. There he gave a lecture entitled *Die Entwicklung der Schwefelsäurefabrikation im Laufe des scheidenden Jahrhunderts* (The Development of Sulfuric Acid Production in the Course of the Late Century). This lecture was published in the *Zeitschrift für angewandte Chemie* in the same year. He wrote there, among other on his invention of the contact method in the production of sulfuric anhydride (sulfur trioxide) in the mid-1870s (Winkler, 1900, p. 738). The Polish chemist Józef Gruszkiewicz (1904) wrote briefly about this method in his article: Already in 1875, the freshly deceased Clemens Winkler announced his dissertation on obtaining fuming sulfuric acid by decomposing concentrated acid at high temperature into SO<sub>2</sub>, O and H<sub>2</sub>O and converting the next SO<sub>2</sub> to SO<sub>3</sub> with catalysts (pp. 865-866).

Mike Haustein (2017) also wrote about this contact method:

In the winter of 1874/75, Clemens Winkler constructed a laboratory system in the Chemical Institute of the *Bergakademie Freiberg*, with which he simultaneously thermally decomposed *Englische Schwefelsäure* [English sulfuric acid]. ... Winkler chose platinum as the contact substance. But he also experimented with palladium, iridium and some metal oxides. In order to obtain the largest possible surface, the Freiberg professor had to apply the precious metal in finely divided form to a porous carrier material. The equally required heat resistance made the choice of asbestos wool. The fibrous material was first impregnated with a soda-alkaline platinum chloride solution, to which an amount of sodium formate sufficient to reduce the platinum was added, the platinum precipitating very finely on the asbestos carrier. The pasty mass was washed extensively and then dried by heating in a water bath. The noble metal content of the catalyst could easily be controlled by the concentration of the platinum chloride solution. At first, Winkler worked with around 8%. In the technical process, a 25% platinum content ultimately proved to be particularly effective. The manufacturing process for the catalytic converter was patented in 1878 ... (pp. 168-169).

It is believed that on February 8, 1886, Winkler discovered germanium. On that day, the editors of the *Berichte der deutschen chemischen Gesellschaft* received his article

in which he informed about the discovery of this chemical element (Winkler, 1886a). He wrote about this discovery as follows:

After several weeks of laborious searching, I can today say with certainty that the argyrodite contains a new element very similar to antimony, but sharply differentiated from it, to which the name "Germanium" may be added (p. 210).

On July 6, 1886, his second article entitled *Mittheilungen über das Germanium* (Communications on Germanium) was published in the *Journal für Praktische Chemie* (Winkler, 1886b).

His last paper entitled *Radioaktivität und Materie* (Radioactivity and Matter) was published in 1904 in the *Berichte der deutschen chemischen Gesellschaft* (Winkler, 1904).

### Winkler's books on chemistry

Almost all of Winkler's books are written in German. Only his textbook has been translated into other languages. His first book under the title *Untersuchungen über die chemische Vorgänge in den Gay-Lussac'schen Condensationsapparaten der Schwefelsäurefabriken* (Investigations into the Chemical Processes in the Gay-Lussac Condensation Apparatus in the Sulfuric Acid Factories) was published in 1867 (Winkler, 1867b).

In 1871, he was a editor of the book written by his father entitled *Geschichtliche Mittheilungen über die erloschenen Silber-, Blei- und Kupferhütten des Erzgebirges und Vogtlandes*. (Historical Information about the Extinct Silver, Lead and Copper Smelters in the Ore Mountains and Vogtland (Winkler, 1871). Four years later, he wrote three chapters entitled *Wismuth, Arsen, Antimon* (Bismuth, Arsenic, Antimony), which were published in a book edited by August Wilhelm Hofmann (1818-1892) (Winkler, 1875b).

In 1876, his book entitled *Anleitung Zur Chemischen Untersuchung Der Industrie-Gase. Qualitative Analyse* (Instructions for the Chemical Investigation of Industrial Gases. Qualitative analysis) was published by J. G. Engelhardt'sche Buchhandlung in Freiberg (Winkler, 1876). A year later, the second volume of this book on quantitative analysis was published (Winkler, 1877).

His book entitled *Die Massanalyse Nach Neuem Titrimetrischem System. Kurzgefasste Anleitung Zur Erlernung Der Titrimethode, Der Chemischen Anschauung Der Neuzeit Gemäss* (The Mass Analysis According to the New Titrimetric System. Brief Instructions for Learning the Titration Method, the Chemical View of Modern Times) appeared in 1883 (Winkler, 1883a). In the same year, his lecture at the Second General German Miners' Days in Dresden, entitled *Wirkt die in unserem Zeitalter stattfindende Massenverbrennung von Steinkohle verändernd auf die Beschaffenheit der Atmosphäre?* (Does the Mass Burning of Hard Coal Taking Place in Our Age Change the Nature of the Atmosphere?) was published in Freiberg (Winkler, 1883b).

The first German edition of his *Lehrbuch Der Technischen Gasanalyse. Kurzgefasste Anleitung Zur Handhabung Gasanalytischer Methoden Von Bewährter Brauchbarkeit* (Textbook of Technical Gas Analysis. Brief Instructions for Handling Gas Analytical Methods of Proven Usefulness) appeared in 1885 (Winkler, 1885a). Seven years later, in 1892, the second edition of this book was published (Winkler, 1892). The third edition was published in 1901 (Winkler, 1901). The fourth and fifth editions were published after Winkler's death, in 1919 and 1927, respectively, under the editorship of Otto Brunck (1866-1946). A reprint of the 1892 edition appeared as an online resource in 2019 (Winkler, 2019).

The first English edition of this book under the title *Handbook Of Technical Gas-Analysis, Containing Concise Instructions for Carrying Out Gas-Analytical Methods of*

*Proved Utility* was published in 1885 in London. The translator was George Lunge (Winkler, 1885b). In the translator's preface he wrote:

EVERY one who has to make gas-analyses for technical purposes is aware that Professor CLEMENS WINKLER is the founder of technical gas-analysis as a distinct branch of analytical Chemistry. A few such processes were, of course, previously known and practised; but Winkler was the first to draw attention to the importance of this subject, to invent suitable apparatus, and to elaborate a complete system of qualitative and quantitative technical gas-analysis..., containing a vast number of new observations and methods, along with a very complete description of the work already done in the same direction by others (p.iii).

The second English edition of this book under the title *Handbook Of Technical Gas-Analysis* appeared in 1902 in London (Winkler, 1902).

The French (1886) edition of this textbook was published in Paris. The translator was Charles Blas (1839-1919), professor at the University of Louvain (Winkler, 1886c).

The first edition of his book entitled *Praktische Uebungen in der Maassanalyse. Anleitung zur Erlernung der Titrirmethode* (Practical Exercises in Dimensional Analysis. Instructions for Learning the Titration Method) was published in 1888 (Winkler, 1888). The second edition of this book appeared 10 years later (Winkler, 1898) and the third was published in 1902. The fourth and fifth editions were published in 1910 and 1920, respectively, under the editorship of O. Brunck.

In 1900, his lecture at the General Miners' Day in Teplitz (1899), entitled *Wann endet das Zeitalter der Verbrennung?* (When does the Era of Burning End?) was published in Freiberg (Winkler, 1900).

### Winkler's correspondence with some great chemists

The Russian-German chemist Victor von Richter (1841-1891) (Sztejnberg, 2020) became the first Russian correspondent-chemist of the German Chemical Society (Kaji, 2003, p. 204). In the years 1869-1872 he sent twelve reports to the journal of this Society *Berichte der deutschen chemischen Gesellschaft* about activities of the Russian Chemical Society.

Richter's correspondence from two meetings of the Russian Chemical Society, held on November 5 (17) and December 3(15), 1870, brought the full version of the Mendeleev Periodic Table (Richter, 1870, p. 992). Richter reported there that Mendeleev had to change the atomic weights of uranium, thorium, cerium and indium in building his table. He also wrote that, following the logic of his Periodic Table, Mendeleev predicted the existence of yet unknown elements: *ekabor* (Eb), *ekaalumini* (El) and *ekasilitsii* (Es). He cited Mendeleev's predictions about the physicochemical properties of these elements: their atomic weights, specific densities, atomic volumes, and the characteristics of their chlorides and oxides. At the end of his correspondence, Richter (1870) wrote: *Interessante Prognosen, wenn es gelänge eines dieser Element wirklich zu entdecken! Der Weg dazu wäre durch die a priori vermutheten Eigenschaften angezeigt*" (Interesting prognoses, if one of these elements could really be discovered! The way to do this would be indicated by the properties assumed a priori) (p. 991).

On August 27, 1875, French chemist Paul Emile Lecoq de Boisbaudran (1838-1912) discovered predicated by Mendeleev *ekaalumini* and named it gallium (Lecoq de Boisbaudran, 1875, pp. 493-495).

Mendeleev's prognosis concerning an existence of *ekabor* also became the truth (Mendeleev, 1958, pp. 90-91). This element was discovered by Swedish chemist Lars Frederic Nilson (1840-1899) in 1879 and named scandium (Nilson, 1879, pp. 645-648).

Discovery of germanium by Winkler decisively confirmed correctness of the Periodic Table of the Elements defined by Mendeleev (Brush, 1996, p. 605; Haustein, 2011, pp. 140-144; Smith, 1949, p. 256; Winkler, 1886, pp. 210-211). In a lecture (Winkler, 1897a, p. 242; Winkler, 1897b, pp. 15-16) held by him on January 11, 1897, in the German Chemical Society at Berlin ), he said:

This discovery [germanium] was not due to the concurrence of favorable circumstances or to a happy accident; it resulted from researches undertaken because of theoretical previsions, and the agreement between the predicted and real properties was such that Mendelejeff considers the discovery of germanium the principal justification of the law of periodicity. ... The success of the bold speculations of Mendelejeff allows us to affirm that the elaboration of the periodic system is a great forward step for science. In the course of only fifteen years all the predictions of the Russian chemist have been confirmed, new elements have been placed in the gaps which he left in his table, and there is reason to hope that it will be the same for those which still remain in the natural system (p. 242).

Richter, in a letter to Winkler dated February 25, 1886, published in Russian by the German chemist Anton Lissner (1885-1970), Professor of Inorganic Chemistry at the *Bergakademie Freiberg* (1945-1955) (Lissner, 1957, p. 51) as well as by the Russian chemist and historian of chemistry Yuri Ivanovich Solov'ev (1983, p. 270), informed him: *что германий, название которого Вы должны сохранить как фактический его отец есть предсказанный Менделеевым элемент экасилиций, Es = 73, наинизший гомолог олова, стоящий в первом большом периоде между Ga (69,8) и As (79,9) ... Экасилиций элемент, которого мы ждем с величайшим напряжением, и во всяком случае ближайшее исследование германия явится самым определенным experimentum crucis для периодической системы* (that Germany, the name of which you must keep as its actual father is the predictions of Mendeleev, the element ekasilici, Es = 73, lowest tin homologue, standing in the first large period between Ga (69,8) and As (79,9) ... The Ekasilici element we are waiting for with the greatest strain, and in any case, the next study of germanium will be the most definite experimentum crucis for the periodic system).

At the Museum of D. I. Mendeleev in St. Petersburg stores several of Winkler's letters to Mendeleev. Two of them were published by the Russian chemist and historian of chemistry Aleksandr Aleksandrovich Makarenya (1930-2015) in 1966 in the Russian journal *Khimiya i zhizn'* (Makarenya, 1966, pp. 55-56). Winkler wrote to Mendeleev in a letter dated February 26, 1886:

*Милостивый государь! Позвольте мне препроводить Вам при сем отдельный оттиск сообщения, согласно которому я обнаружил в найденном здешнем серебряном минерале новый элемент германий. Первоначально я был того мнения, что это элемент заполняет имеющийся в столь чрезвычайно остроумно составленной Вами периодической системе пробел между сурьмой и висмутом, т. е. что он, следовательно, представляет Вашу экасурьму; однако все указывает на то, что здесь мы имеем дело с предсказанным Вами экакремнием. Я надеюсь вскоре иметь возможность сообщить Вам подробности относительно нового чрезвычайно интересного тела; сегодня я ограничусь тем, что уведомя Вас об этом новом торжестве Вашего гениального исследования и засвидетельствую Вам свое высочайшее почтение. Клеменс Винклер 26 февраля 1886 г.* (Your Majesty! Allow me to transmit to you in this separate reprint of a report according to which I have discovered a new element, germanium, in a silver mineral found here. Initially, I was of the opinion that this element is filled with the gap between antimony and bismuth in a very ingeniously compiled by you periodic table, that is, that it, therefore, represents your



ekaantimony; however, everything points to the fact that here we are dealing with the ekasilitsii predicted by you. I hope soon to be able to give you details on a new extremely interesting body; today I will confine myself to informing you of this new triumph of your ingenious research and to pay you my highest respect. Clemens Winkler February 26, 1886) (p. 55).

On March 7, 1886, Mendeleev announced that he had received this letter at a Meeting of the Chemical Department of the Russian Physicochemical Society and in the April issue of the journal of this Society, Winkler's article entitled *Germanium, a new metalloid* was published (Makarenya, 1966, p. 55).

On March 1, 1886, Mendeleev sent a congratulatory telegram to Winkler. The Russian chemist and historian of chemistry Nikolay Aleksandrovich Figurovskiy (1983) wrote about their correspondence as follows:

*Как явствует из дальнейшей переписки между Винклером и Менделеевым, в частности из письма от 5 марта 1886 г. и от 1 июня 1887 г. ..., Винклер очень беспокоился, согласился ли Менделеев с предложенным названием элемента «германий» и не будет ли настаивать на своем названии «экасилиций». Винклер писал в своих письмах, среди прочего: ... Ваша любезная, очень обрадовавшая меня телеграмма, за которую приношу Вам свою нижайшую благодарность... я забыл Вам сказать, что предложение о том, что это (новый элемент ...) есть предсказанный Вами экасилиций, высказано не мною, а В. фон Рихтером в Бреславле, и он об этом сообщает в Berichte der Deutschen chemischen Gessellschaft. В письме ко мне почти одновременно с ним это же предложение высказал и Лотар Мейер в Тюбингене (As is evident from further correspondence between Winkler and Mendeleev, in particular from a letter dated March 5, 1886 and June 1, 1887..., Winkler was very worried if Mendeleev agreed with the proposed name for the element “germanium”, and whether he will not insist on its name “ekasilitsii”. Winkler wrote in his letters, among other things: ... Your kind telegram, which made me very happy, for which I bring you my lowest gratitude ...I forgot to tell you that the sentence that this (new element ...) is predicted by you ekasilitsii, expressed not by me, but V. von Richter in Breslau, and he reports this in Berichte der Deutschen chemischen Gessellschaft. In a letter to me, almost simultaneously with him, the same sentence was also expressed by [the German chemist] Lothar Meyer [1830-1895] in Tübingen) (pp. 127-128).*

Mendeleev accepted the name of germanium for the element discovered by Winkler. He informed him about it in a letter sent on April 21, 1886. Here is an excerpt (Makarenya, 1966) from Winkler's reply:

*Милостивый государь! Вы, по всей вероятности, не представляете себе ту исключительную радость, которую Вы мне доставили Вашим любезным благожелательным письмом от 21 апреля. Содержание его и то, что Вы согласны с наименованием германия, очень меня успокоило, так как меня бы угнетало Ваше несогласие с выбором названия ... (Your Majesty! You, in all likelihood, do not imagine the exceptional joy that you brought me with your kind, benevolent letter of April 21st. Its content and the fact that you agree with the name germanium reassured me very much, since I would be depressed by your disagreement with the choice of the name ...) (p. 56).*

Mendeleev and V. v. Richter's letters to Winkler in German dated February 14/26 and February 25, 1866, respectively, were presented by Hanns C. A. Winkler in one of the chapters in the book entitled *Clemens Winkler. Gedenkschrift zur 50. Wiederkehr seines Todestages* (Winkler, 1954, pp. 38-39).

## CONCLUSION

Clemens Winkler (1838-1904) was one of the prominent chemists of the second half of the XIX century. He received many scientific honours. Among them are a membership of the Academies of Sciences and Scientific Societies, as well as distinctions and decorations.

On December 9, 1878, he became member of the *Kaiserlich Königlich Leopoldinisch-Carolingischen deutschen Akademie der Naturforscher* (Imperial Royal Leopoldine-Carolingian German Academy of Natural Scientists) in Halle. One year later, he was elected a corresponding member of the Imperial Geological Institute in Vienna. He became a member of the Physical Association in Frankfurt a. Main (1887), the Society of Science in Leipzig (1890), the Swedish Society of Sciences in Stockholm (1892), the Dutch Society of Sciences in Harlem (1897).

In 1897, he became an honorary member of the Association of German Chemists. In 1900, he was elected a corresponding member of the Royal Prussian Academy of Sciences (Papperitz, 1904, p. 10).

He was the owner of the *Komturkreuzes I. Klasse des Königlich Sächsischer Albrechts-ordens* (Kingly Saxon Albrecht-Order) and the Knight's Cross of the Merit I. Class (Papperitz, 1904, p. 10).

On January 20, 1896, the *Verein zur Beförderung des Gewerbefleißes* (Association for the Promotion of Industry) in Berlin conferred on him the golden Delbrück Medal “for merits, for development technical analysis of gases” (Anonymous, 1904, p. 900; Papperitz, 1904, p. 10; Prokop, 1954, p. 94).

Winkler's books appeared mainly in Germany. Only his textbook on technical gas analysis has been published in Great Britain and France. Some authors also wrote about his life and work. For instance, Erwin Papperitz wrote a 12-page article about him in 1904 (Papperitz, 1904). One year later, Winkler's obituary was written by Theodor Döring and published in the *Zeitschrift für angewandte Chemie* (Döring, 1905). In 1906, Otto Brunck wrote his obituary, which was published in the *Berichte der deutschen chemischen Gesellschaft* (Brunck, 1906). An article by Bernhard Sorms about him was published in 1990 in the *History and Technology* (Sorms, 1990). On the 100th anniversary of his death, two articles by Klaus Volke were published (Volke, 2004a; Volke, 2004b). Mike Haustein's 104-page biographical book about Winkler was published in 2004 in Frankfurt am Main (Haustein, 2004). Reviews of this book have been written by Walter Jansen (2005) and Klaus Möckel (2005). In 2012, Reiner Salzer wrote an article entitled *Der Jungchemiker Clemens Winkler und das Blaufarbenwerk Niederpfannenstiel* (The young chemist Clemens Winkler and the Blue Color Works in Niederpfannenstiel) (Salzer, 2012). In 2014, R. Klaus Müller wrote briefly about his life and work in one of the chapters of the book entitled *Important Figures of Analytical Chemistry* (Müller, 2014, pp. 70-71). Several authors have written articles about Winkler and the Germanium he discovered (Haustein, 2011a; Haustein, 2011b; Marshall & Marshall, 2001; Schwedt, 2009; Weinert, 2020).

After Winkler, not only his papers, books and letters survived. In addition, several of his portraits and photos were produced. His portraits can also be found in the book by H. M. Smith (1949, p. 256) and in the book entitled *Discovery of the Elements* by the American chemist and historian of chemistry Mary Elvira Weeks (1892-1975) (Weeks, 1956, p. 683). One of his photograph is from the Edgar Fahs Smith Chemistry Collection (“Winkler, Clemens (1838”, n.d.). The photo of Winkler and Mendeleev (Figure 3) taken in March 1900 in Berlin can be found in the articles by Jansen (2005, p. 43), Makarenya (1966, p. 55) and Marshall & Marshall, 2008, p. 21). According to another source, the photo was taken six years earlier, during Mendeleev's stay in Freiberg in May 1894

(Winkler, 1954, p. 43).



*Fig. 3. Dmitri Ivanovich Mendeleev and Clemens Winkler (left, and right respectively) (“Clemens Winkler zusammen”, 1900)*

A Monument in honor of Winkler was erected in Freiberg, the town where he was born (“Clemens-Winkler-Denkmal”, 2013). In addition, an image of a commemorative plaque made in his honor can also be found in the literature. It was funded by the *Gesellschaft Deutscher Chemiker* (Society of German Chemists) and unveiled at the Old Chemical Institute of the *Technischen Universität Bergakademie* (Technical University Bergakademie) in Freiberg, on October 20, 2004, on the occasion of the 100th Anniversary of his death (“Historische Stätte der”, 2021). It has the following inscription:

HISTORICAL SITES / OF CHEMISTRY / IN THIS BUILDING LIVED, / RESEARCHED AND TAUGHT / CLEMENS ALEXANDER WINKLER / (1838-1904) / PROFESSOR AT THE ROYAL. - SAXON. / BERGAKADEMIE FROM 1873-1902 / CLEMENS WINKLER CARRIED OUT / PIONEERING WORK IN THE FIELDS OF / INORGANIC, ANALYSTS AND / TECHNICAL CHEMISTRY. THE FLUE GAS DESULPHURISATION PROCESS HE DEVELOPED MADE HIM / A PIONEER IN MODERN ENVIRONMENTAL PROTECTION TECHNOLOGIES. ON FEBRUARY 6TH 1886 HE DISCOVERED / THE GERMANIUM HERE, WHEREBY THE / PROOF OF THE CORRECTNESS OF THE PERIODIC / TABLE OF THE ELEMENTS HAS BEEN ESTABLISHED. / THE RUSSIAN SCHOLAR DMITRI / MENDELEEV WAS A GUEST IN THIS HOUSE IN 1894. / UNVEILED ON OCTOBER 20, 2004 / IN THE 100TH YEAR OF CLEMENS WINKLER DEATH / GDCh SOCIETY OF GERMAN CHEMISTS (“Clemens Winkler, Gedenktafel”, 2008).

The name of this eminent German chemist is loudly heard among chemists in Germany. There is one award associated with his name. The *Clemens-Winkler Medal* is awarded by the Division of Analytical Chemistry of the German Chemical Society every two years. The award is accompanied by a certificate and a gold medal. The German analytical chemists receive this award for their “committed to the scientific development and the promotion and recognition of analytical chemistry deserved” (“Clemens-Winkler Medal”, 2021).

## BIBLIOGRAPHIC REFERENCES

*200th Anniversary of Berlin Academy.* (1900). Public Domain. Retrieved from [https://commons.wikimedia.org/wiki/Category:Portrait\\_photographs\\_of\\_Dmitri\\_Mendeleev#/media/File:200\\_y\\_Anniversary\\_of\\_Berlin\\_Academy\\_1900.jpg](https://commons.wikimedia.org/wiki/Category:Portrait_photographs_of_Dmitri_Mendeleev#/media/File:200_y_Anniversary_of_Berlin_Academy_1900.jpg)

Anonymous (1904). Klemens Winkler. *Chemik Polski*, 4(45), 900. (in Polish). Retrieved from <http://cybra.lodz.pl/Content/531>

Baeyer, A. von., Villiger, V., Hottenroth, V., & Hallensleben, R. (1905). *Adolf von Baeyer's Gesammelte Werke* (Adolf von Baeyer's Collected Works). Erster Band. Braunschweig: Druck und Verlag von Friedrich Vieweg und Sohn. (in German). Retrieved from <https://archive.org/details/adolfvonbaeyersg01baey>

Boeck, G., & Zott, R. (2007). Dmitrij Ivanovič Mendeleev (1834–1907): Zum 100. Todestag. *Chemie in unserer Zeit*, 41(1), 12-20. <http://doi.org/10.1002/ciuz.200700406>

Brunck, O. (1906). Clemens Winkler. *Berichte der deutschen chemischen Gesellschaft*, 39(4), 4491-4548. <https://doi.org/10.1002/cber.190603904164>

Brush, S. G. (1996). The Reception of Mendeleev's Periodic Law in America and Britain. *Isis*, 87(4), 594-628. <http://dx.doi.org/10.1086/357649>

*Clemens Winkler als Professor in Freiberg.* (1875). Public Domain. Retrieved from [https://fr.wikipedia.org/wiki/M%C3%A9daille\\_Clemens-Winkler#/media/Fichier:Winkler\\_1875.png](https://fr.wikipedia.org/wiki/M%C3%A9daille_Clemens-Winkler#/media/Fichier:Winkler_1875.png)

*Clemens Winkler, Gedenktafel in Freiberg.* (2008). Retrieved from <https://commons.wikimedia.org/wiki/File:Clemenswinklerplaque.jpg>

*Clemens Winkler zusammen mit Dimitri Mendelejew während eines Besuchs in Berlin am 19.03.1900.* (1900). Public Domain. Retrieved from [https://commons.wikimedia.org/wiki/File:Winkler\\_mendelejew.png](https://commons.wikimedia.org/wiki/File:Winkler_mendelejew.png)

*Clemens-Winkler-Denkmal, Wallstraße, Freiberg.* (2013). Retrieved from [https://commons.wikimedia.org/wiki/File:Clemens-Winkler-Denkmal\\_Freiberg.JPG](https://commons.wikimedia.org/wiki/File:Clemens-Winkler-Denkmal_Freiberg.JPG)

*Clemens-Winkler Medal from the GDCh Division of Analytical Chemistry.* (2021). Retrieved from <https://en.gdch.de/network-structures/divisions/analytische-chemie/awards-honors/clemens-winkler-medal.html>

Donnan, F. G. (1948). Ernst Julius Cohen. 1869-1944. *Obituary Notices of Fellows of the Royal Society*, 5(16), 666-687. Retrieved from <http://www.jstor.org/stable/768764>

Döring, Th. (1905). Zur Erinnerung an Clemens Winkler. *Zeitschrift für angewandte Chemie*, 18(1), 1-7. <http://doi.org/10.1002/ange.19050180102>

Figurovskiy, N. A. (1983). *Dmitrii Ivanovich Mendeleev, 1834-1907.* (2-ie izd.) (D. I. Mendeleev, 1834-1907), 2nd ed. Moskva: Nauka, pp. 127-128 (in Russian).

Gruszkiewicz, J. (1904). Teorya i praktyka otrzymywania kw. siarkowego na drodze kontaktowej (Theory and Practice of Obtaining Sulfuric Acid by the Contact Method). *Chemik Polski*, 4(44), 861-870 (in Polish). Retrieved from [http://cybra.p.lodz.pl/Content/529/ChePol\\_r.4\\_nr44.pdf](http://cybra.p.lodz.pl/Content/529/ChePol_r.4_nr44.pdf).

Harrow, B. (1920). *Eminent Chemists of Our Time.* New York: D. Van Nostrand Company. Retrieved from <https://archive.org/details/eminentchemistso00harruoft/page/n7/mode/2up>

Haustein, M. (2017). Das Kontaktverfahren: Eine Innovation aus dem sächsischen Hüttenwesen.

*Mitteilungen, Gesellschaft Deutscher Chemiker / Fachgruppe Geschichte der Chemie.* (Frankfurt/Main), 25, 164-189. Retrieved from [https://www.gdch.de/fileadmin/downloads/Netzwerk\\_und\\_Strukturen/Fachgruppen/Geschichte\\_der\\_Chemie/Mitteilungen\\_Band\\_25/2017-25-08\\_neu.pdf](https://www.gdch.de/fileadmin/downloads/Netzwerk_und_Strukturen/Fachgruppen/Geschichte_der_Chemie/Mitteilungen_Band_25/2017-25-08_neu.pdf).

Haustein, M. (2011a). Germanium. Experimentum crucis für eine kühne Theorie, *ACAMONTA – Zeitschrift für Freunde und Förderer der TU Bergakademie Freiberg*, 18, 140-144. Retrieved from [http://tu-freiberg.de/sites/default/files/media/freunde-und-foerderer-6089/pdf/zsfreunde2011\\_Seiten\\_105bis167.pdf](http://tu-freiberg.de/sites/default/files/media/freunde-und-foerderer-6089/pdf/zsfreunde2011_Seiten_105bis167.pdf)

Haustein, M. (2011b). Germanium. Die Lücke im Periodensystem. *Chemie in unserer Zeit*, 45(6), 398-405. <https://doi.org/10.1002/ciuz.201100549>

Haustein, M. (2004). *Clemens Winkler. Chemie war sein Leben*. 1. Auflage. Frankfurt am Main: Harri Deutsch.

*Historische Stätte der Chemie. Wirkungsstätte von Clemens Winkler in Freiberg*. (2021). Retrieved from <https://www.gdch.de/gdch/historische-staetten-der-chemie.html>

Jansen, W. (2005). Buchbesprechung: Clemens Winkler — Chemie war sein Leben von Mike Haustein. *Chemkon*, 12(1), 43-44. <https://doi.org/10.1002/ckon.200590005>

Kaji, M. (2003). Mendeleev's Discovery of the Periodic Law: The Origin and the Reception. *Foundation of Chemistry*, 5, 189-214. <https://doi.org/10.1023/A:1025673206850>

Kauffman, G. B. (1992). Sophus Mads Jørgensen. A Danish Platinum Metals Pioneer. *Platinum Metals Review*, 36(4), 217-223.

Retrieved from <https://www.technology.matthey.com/article/36/4/217-223/>

Kauffman, G. B., & Molayem, E. (1990). Alfonso Cossa (1833–1902), a Self-Taught Italian Chemist. *Ambix*, 37(1), 20-34. <http://doi.org/10.1179/amb.1990.37.1.20>

Kauffman, G. B., & NiiNistö, L. (1998). Evard Immanuel Hjelt (1855–1921): Finnish Chemist and Historian of Chemistry. *The Chemical Educator*, 3, 1-16. <https://doi.org/10.1007/s00897980208a>

Lecoq de Boisbaudran. (1875). Caractères chimiques et spectroscopiques d'un nouveau métal, le Gallium, découvert dans une blende de la mine de Pierrefitte, vallée d'Argelès (Pyrénées). *Comptes Rendus Hebdomadaires des Séances de L'Academie des Sciences*, 81, 493-495. Retrieved from <https://gallica.bnf.fr/ark:/12148/bpt6k3038w/f490.item>

Lissner, A. (1957). Svyazi D. I. Mendelejeva s Gornoy akademiyei vo Freyberge (D. I. Mendeleev's Connections with the Mining Academy in Freiberg). *Voprosy Istorii Yestestvoznaniya i Tekhniki*, 5, 50-55. (in Russian). Retrieved from <http://annales.info/sbo/contens/viet.htm#005>

Lissner, A. (1954). Clemens Winkler, Der Bedeutende Chemiker. In H. C. A. Winkler, A. Lissner, A. Lance, & R. Prokop, *Clemens Winkler. Gedenkschrift zur 50. Wiederkehr seines Todestages* (pp. 51-68). Berlin: Akademie-Verlag. Retrieved from

<https://sachsen.digital/werkansicht/28667/9/0?cHash=859d3f7a2f3fb4a72855ee395386c598>

Makarenaya, A. (1966). Iz perepiski D. I. Mendelejeva i K. A. Vinklera (From the Correspondence Between D. I. Mendeleev and K. A. Winkler). *Khimiya i zhizn'*, 7, 55-56. Retrieved from [http://publ.lib.ru/ARCHIVES/H/%27%27Himiya\\_i\\_jizn%27%27%27/\\_Himiya\\_i\\_jizn"\\_1966\\_.html](http://publ.lib.ru/ARCHIVES/H/%27%27Himiya_i_jizn%27%27%27/_Himiya_i_jizn)

Marshall, J. L., & Marshall, V. R. (2001). Rediscovery of the Elements. Germanium: Freiberg, Germany. *The Hexagon, Summer*. 20-22. Retrieved from [https://digital.library.unt.edu/ark:/67531/metadc111177/m2/1/high\\_res\\_d/metadc111177.pdf](https://digital.library.unt.edu/ark:/67531/metadc111177/m2/1/high_res_d/metadc111177.pdf).

McCay, L. W. (1930). My Student Days in Germany. *Journal of Chemical Education*, 7 (5), 1081-1099. <http://doi.org/10.1021/ed007p1081>

Möckel, K. (2005). Clemens Winkler. Chemie war sein Leben. Von Mike Haustein. *Angewandte Chemie*, 117(7), 1019-1020. <https://doi.org/10.1002/ange.200485253>

Müller, R. K. (2014). Growth into Scientific Discipline: The Nineteenth Century. In D. T. Burns, R. K. Müller, R. Salzer, G. Werner, *Important Figures of Analytical Chemistry from Germany in Brief Biographies. From the Middle Ages to the Twentieth Century* (pp. 49-95). Cham, Heidelberg, New York, Dordrecht, London: Springer. [https://doi.org/10.1007/978-3-319-12151-2\\_3](https://doi.org/10.1007/978-3-319-12151-2_3)

Nilson, L. F. (1879). Sur le scandium, élément nouveau. *Comptes Rendus Hebdomadaires des Séances de L'Academie des Sciences*, 88, 645-648. Retrieved from [https://fr.wikisource.org/wiki/Livre:Comptes\\_rendus\\_hebdomadaires\\_des\\_s%C3%A9ances\\_de\\_l%E2%80%99Acad%C3%A9mie\\_des\\_sciences,\\_tome\\_088,\\_1879.djvu](https://fr.wikisource.org/wiki/Livre:Comptes_rendus_hebdomadaires_des_s%C3%A9ances_de_l%E2%80%99Acad%C3%A9mie_des_sciences,_tome_088,_1879.djvu)

Oesper, R. E. (1945). Hans Landolt (1831-1910). *Journal of Chemical Education*, 22(4), 158-162. <https://doi.org/10.1021/ed022p158>

Papperitz, E. (1904). *Clemens Winkler*. Freiberg. Retrieved from <https://digital.slub-dresden.de/werkansicht/df/385478/1>

Prokop, R. (1954). Clemens Winkler als Direktor der Bergakademie. Clemens Winkler. Sein Leben in Stichworten und Daten nach eigenen Aufzeichnungen. In H. C. A. Winkler, A. Lissner, A. Lance, & R. Prokop, *Clemens Winkler. Gedenkschrift zur 50. Wiederkehr seines Todestages* (pp. 87-96). Berlin: Akademie-Verlag. Retrieved from

<https://sachsen.digital/werkansicht/28667/9/0?cHash=859d3f7a2f3fb4a72855ee395386c598>

Richter, V. v. (1870). V. v. Richter, aus Petersburg am 6/18. Decbr. *Berichte der deutschen chemischen Gesellschaft*, 3(2), 988-992. <https://doi.org/10.1002/cber.18700030296>

Salzer, R. (2012). *Der Jungchemiker Clemens Winkler und das Blaufarbenwerk Niederpfannenstiel*. Mitteilungen. Gesellschaft Deutscher Chemiker / Fachgruppe Geschichte der Chemie (Frankfurt/Main), 22, 108-116. Retrieved from [https://www.gdch.de/fileadmin/downloads/Netzwerk\\_und\\_Strukturen/Fachgruppen/Geschichte\\_der\\_Chemie/Mitteilungen\\_Band\\_22/2012-22-08.pdf](https://www.gdch.de/fileadmin/downloads/Netzwerk_und_Strukturen/Fachgruppen/Geschichte_der_Chemie/Mitteilungen_Band_22/2012-22-08.pdf).

Schwedt, G. (2009). Freiberg in Sachsen. *Chemie in Unserer Zeit*. 43(3), 182-184. <https://doi.org/10.1002/ciuz.200990033>

Smith, H. M. (1949). *Torchbearers of Chemistry. Portraits and Bibliography of Scientists Who Have Contributed to the Making of Modern Chemistry*. New York: Academic Press Inc., Publishers.

Solov'ev, Yu. I. (1983). *Istoriya khimii: Razvitiye khimii s drevneyshikh vremen do kontsa XIX v. Posobiye dlya uchiteley* (2-ye izd.) [History of Chemistry: The Development of Chemistry from Ancient Times to the end of the Nineteenth Century. A Handbook for Teachers (2nd ed.)]. Moskva: Prosveshcheniye.

Sorms, B. (1990). Clemens Winkler – A Chemist at the Freiberg Mining Academy During the 2nd Phase of Industrialization in Germany. *History and Technology*, 7, 51-61. <https://doi.org/10.1080/07341519008581763>

Sztejnberg, A. (2021a). Thomas Edward Thorpe (1845-1925) – The Distinguished British Chemist and historian of chemistry of the Second Half of the XIX Century. (Thomas Edward Thorpe (1845-1925) - El químico británico distinguido e historiador de la química de la segunda mitad del siglo XIX). *Revista CENIC Ciencias Químicas*, 52(2), 105-120. Retrieved from <https://revista.cnic.cu/index.php/RevQuim/article/view/934>

Sztejnberg, A. (2021b). Albert Ladenburg (1842-1911) – The Distinguished German Chemist and Historian of Chemistry of the Second Half of the XIX Century (To the 110th Anniversary of His Death). *Substantia*, Just Accepted. DOI. 10.36253/Substantia-1231

Sztejnberg, A. (2021c). The Eminent Russian – German Chemist Friedrich Konrad Beilstein (1838-1906) in the Literature between the 19<sup>th</sup> and 21<sup>st</sup> centuries. *Substantia*,

5(1), 135-156. <https://doi.org/10.36253/Substantia-1097>

Sztejnberg, A. (2020). Victor Von Richter (1841-1891) – The Famous Russian-German Chemist, Author of Excellent Academic Textbooks on Chemistry. *Revista CENIC Ciencias Químicas*, 51(2), 369-378. Retrieved from <https://revista.cnic.cu/index.php/RevQuim/article/view/808>

Sztejnberg, A. (2018). Dmitri Ivanovich Mendeleev (1834 – 1907), Prominent Russian Scientist. References to His Great Scientific Achievements in the Literature between 1871 and 1917. *Revista CENIC Ciencias Químicas*, 49, 1-13. Retrieved from <https://revista.cnic.cu/index.php/RevQuim/article/view/224>

Tilden, W. (1918). *Sir William Ramsay. K.C.B., F.R.S. Memorials of His Life and Work*. London: Macmillan and CO., Limited. Retrieved from <https://archive.org/details/sirwilliamramsay00tilduoft>

Tutton, A. E. H. (1925). Sir Edward Thorpe, C.B., F.R.S. *Nature*, 115(2888), 343-345. <https://doi.org/10.1038/115343a0>

Volke, K. (2004a). Clemens Winkler – zum 100. Todestag. *Chemie in unserer Zeit*, 38(5), 360-361. <https://doi.org/10.1002/ciuz.200490078>

Volke, K. (2004b). Clemens Winkler und der Umweltschutz: Zum 100. Todestag des bedeutendsten Freiburger Chemikers. *Mitteilungen. Gesellschaft Deutscher Chemiker / Fachgruppe Geschichte der Chemie (Frankfurt/Main)*, 17, 111-130. Retrieved from [https://www.gdch.de/fileadmin/downloads/Netzwerk\\_und\\_Strukturen/Fachgruppen/Geschichte\\_der\\_Chemie/Mitteilungen\\_Band\\_17/2004-17-08.pdf](https://www.gdch.de/fileadmin/downloads/Netzwerk_und_Strukturen/Fachgruppen/Geschichte_der_Chemie/Mitteilungen_Band_17/2004-17-08.pdf).

Weeks, M. E. (1956). *Discovery of the Elements* (6th ed.). Easton: Journal of Chemical Education.

Weinert, C. S. (2020). Die Chemie ist Schwierig: Winkler and the Discovery of Germanium. *Bulletin for the History of Chemistry*, 45(1), 8-15. Retrieved from <http://acshist.scs.illinois.edu/bulletin/bull20-vol45-1.php>

Winkler, C. (2019). *Lehrbuch Der Technischen Gasanalyse. Kurzgefasste Anleitung Zur Handhabung Gasanalytischer Methoden Von Bewährter Brauchbarkeit*. Nachdruck der Ausgabe von 1892. Norderstedt Hansebooks GmbH. Online-Resource. Retrieved from <https://www.worldcat.org/title/lehrbuch-der-technischen-gasanalyse-kurzgefasste-anleitung-zur-handhabung-gasanalytischer-methoden-von-bewahrter-brauchbarkeit/oclc/1190348222?referer=di&ht=edition>

Winkler, C. (1904). Radioaktivität und Materie. *Berichte der deutschen chemischen Gesellschaft*, 37(2), 1655-1882. <https://doi.org/10.1002/cber.19040370271>

Winkler, C. (1902). *Handbook Of Technical Gas-Analysis*. Second English Edition. (G. Lunge, Trans.). London: Gurney and Jackson. (Original work published 1885). Retrieved from <https://archive.org/details/handbookoftechni031011mbp/page/n5/mode/2up>

Winkler, C. (1901). *Lehrbuch Der Technischen Gasanalyse. Kurzgefasste Anleitung Zur Handhabung Gasanalytischer Methoden Von Bewährter Brauchbarkeit*. Dritte Auflage. Leipzig: Verlag von Arthur Felix. Retrieved from <https://archive.org/details/lehrbuchdertech00winkgoog/page/n5/mode/2up>

Winkler, C. (1900). Die Entwicklung der Schwefelsäurefabrikation im Laufe des scheidenden Jahrhunderts. *Zeitschrift für angewandte Chemie*, 13(30), 731-739. <http://doi.org/10.1002/ange.19000133002>

Winkler, C. (1898). *Praktische Uebungen in der Maassanalyse. Anleitung zur Erlernung der Titrirmethode*. Zweite Auflage. Freiberg: J. G. Engelhardt'sche Buchhandlung (M. Isensee). Retrieved from <https://www.worldcat.org/title/praktische-uebungen-in-der-maassanalyse-anleitung-zur-erlernung-der-titrirmethode/oclc/6546997>

Winkler, C. (1897a). *The discovery of New Elements within the Last Twenty-Five Years*.

Annual Report of the Board of Regents of the Smithsonian Institution. Washington: Government Printing Office, pp. 237-246. Retrieved from <https://archive.org/details/annualreportofbo1897smit/page/236/mode/2up>

Winkler, C. (1897b). Ueber die Entdeckung neuer Elemente im Verlaufe der letzten fünfundzwanzig Jahre und damit zusammenhängende Fragen. *Berichte der deutschen chemischen Gesellschaft*, 30(1), 6-21. <http://doi.org/10.1002/cber.18970300103>

Winkler, C. (1892). *Lehrbuch Der Technischen Gasanalyse. Kurzgefasste Anleitung Zur Handhabung Gasanalytischer Methoden Von Bewährter Brauchbarkeit*. Zweite Auflage. Freiberg: J. G. Engelhardt'sche Buchhandlung (M. Isensee). Retrieved from <https://archive.org/details/lehrbuchdertechn00winkrich/page/n7/mode/2up>

Winkler, C. (1888). *Praktische Uebungen in der Maassanalyse. Anleitung zur Erlernung der Titrirmethode*. Freiberg: J. G. Engelhardt'sche Buchhandlung (M. Isensee). Retrieved from

<https://archive.org/details/praktischeuebun01winkgoog/page/n5/mode/2up>

Winkler, C. (1886a). Germanium, Ge, ein neues, nichtmetallisches Element. *Berichte der deutschen chemischen Gesellschaft*, 19(1), 210-211. <https://dx.doi.org/10.1002/cber.18860190156>

Winkler, C. (1886b). Mittheilungen über das Germanium. *Journal für Praktische Chemie*, 34(1), 177-229. <https://doi.org/10.1002/prac.18860340122>

Winkler, C. (1886c). *Manuel Pratique De L'Analyse Industrielle Des Gaz* ( C. Blas, Trans.). Paris: F. Savy. (Original work published 1885). Retrieved from [https://katalog.ub.tu-freiberg.de/Search/Results?access=all&submit=&type=AllFields&lookfor=oclc\\_num:23531121](https://katalog.ub.tu-freiberg.de/Search/Results?access=all&submit=&type=AllFields&lookfor=oclc_num:23531121)

Winkler, C. (1885a). *Lehrbuch Der Technischen Gasanalyse. Kurzgefasste Anleitung Zur Handhabung Gasanalytischer Methoden Von Bewährter Brauchbarkeit*. Freiberg: J. G. Engelhardt'sche Buchhandlung (M. Isensee).

Winkler, C. (1885b). *Handbook Of Technical Gas-Analysis, Containing Concise Instructions for Carrying Out Gas-Analytical Methods of Proved Utility*. (G. Lunge, Trans.). London: John Van Voorst. (Original work published 1885). Retrieved from <https://archive.org/details/handbookoftechni00winkrich/page/n3/mode/2up>

Winkler, C. (1883a). *Die Massanalyse Nach Neuem Titrimetrischem System. Kurzgefasste Anleitung Zur Erlernung Der Titrirmethode, Der Chemischen Anschauung Der Neuzeit Gemäss*. Freiberg: J. G. Engelhardt'sche Buchhandlung (M. Isensee). Retrieved from <https://babel.hathitrust.org/cgi/pt?id=wu.89097690416&view=1up&seq=5>

Winkler, C. (1883b). *Wirkt die in unserem Zeitalter stattfindende Massenverbrennung von Steinkohle verändernd auf die Beschaffenheit der Atmosphäre?* (Vortrag, gehalten beim Zweiten Allgemeinen Deutschen Bergmannstage in Dresden am 5. September 1883). Freiberg: Druck von Ernst Mauckisch. Retrieved from <https://sachsen.digital/werkansicht/30054/3/0?cHash=b92e6b4f70ec8b126c72bae14ace2e3e>

Winkler, C. (1877). *Anleitung Zur Chemischen Untersuchung Der Industrie-Gase. Zweite Abtheilung: Quantitative Analyse*. Freiberg: J. G. Engelhardt'sche Buchhandlung (M. Isensee). Retrieved from <https://babel.hathitrust.org/cgi/pt?id=nyp.33433062728245&view=1up&seq=177>

Winkler, C. (1876). *Anleitung Zur Chemischen Untersuchung Der Industrie-Gase. Erste Abtheilung: Qualitative Analyse*. Freiberg: J. G. Engelhardt'sche Buchhandlung (M. Isensee). Retrieved from <https://babel.hathitrust.org/cgi/pt?id=nyp.33433062728245&view=1up&seq=9>



Winkler, C. (1875a). Versuche über die Ueberführung der schwefligen Säure in Schwefelsäureanhydrid durch Contactwirkung behufs Darstellung von rauchender Schwefelsäure. *Dinglers polytechnisches Journal*, 218, 128-139. Retrieved from <http://dingler.culture.hu-berlin.de/article/pj218/ar218036>

Winkler, C. (1875b). Wismuth, Arsen, Antimon. In A. W. Hofmann (Ed.), *Bericht über die Entwicklung der Chemischen Industrie während des letzten Jahrzehends im Verein mit Freunden und Fachgenossen* (pp. 953-985). Erste Hälfte. Braunschweig: Druck und Verlag von Friedrich Vieweg und Sohn. Retrieved from <https://archive.org/details/berichtberdieen00hofmgoog/page/n17/mode/2up>

Winkler, C. (Ed.). (1871). *Geschichtliche Mitteilungen über die erloschenen Silber-, Blei- und Kupferhütten des Erzgebirges und Vogtlandes. Bearbeitetes hinterlassenes Manuskript seines Vaters Curt Alexander Winkler*. Freiberg: Verlag I. G. Engelhardt (M. Isensee).

Winkler, C. (1867a). Beiträge zur Kenntniss des Indiums. *Journal für Praktische Chemie*, 102(1), 273-297. <https://doi.org/10.1002/prac.18671020139>

Winkler, C. (1867b). *Untersuchungen über die chemische Vorgänge in den Gay-Lussac'schen Condensationsapparaten der Schwefelsäurefabriken*. Freiberg: I. G. Engelhardt'sche Sortiments-Buchhandlung (M. Isensee). Retrieved from

<https://www.worldcat.org/title/untersuchungen-uber-die-chemische-vorgaenge-in-den-gay-lussacschen-condensationsapparaten-der-schwefelsaurefabriken/oclc/504689042>

Winkler, C. (1865). Beiträge zur Kenntniss des Indiums. *Journal für Praktische Chemie*, 94(1), 1-9. <https://doi.org/10.1002/prac.18650940101>

Winkler, C. (1864a). Ueber Siliciumlegirungen und Siliciumarsenmetalle. *Journal für Praktische Chemie*, 91(1), 193-208. <https://doi.org/10.1002/prac.18640910134>

Winkler, C. (1864b). Die maassanalytische Bestimmung des Wassers in organischen Flüssigkeiten.

*Journal für Praktische Chemie*, 91(1), 209-213. <https://doi.org/10.1002/prac.18640910135>

Winkler, C. (1864c). Die Thompson'sche Trennungsmethode für Kobalt und Nickel. *Journal für Praktische Chemie*, 91(1), 109-110. <http://doi.org/10.1002/prac.18640910119>

Winkler, C. (1864d). Ueber die Kobaltsäure. *Journal für Praktische Chemie*, 91(1), 213-220. <https://doi.org/10.1002/prac.18640910136>

Winkler, C. (1864e). Zur Kenntniss der Kobaltsäure. *Journal für Praktische Chemie*, 91(1), 351-359. <https://doi.org/10.1002/prac.18640910155>

Winkler, C. (1859). Ueber die Zusammensetzung des Condurrits. *Berg- und Hüttenmännische Zeitung*, 18 (42), 383-384. Retrieved from <https://opacplus.bsb-muenchen.de/Vta2/bsb10228254/bsb:6118666?page=391>

Winkler, Clemens (1838-1904). *smith\_pw724\_2\_s*. (n.d.). Retrieved from <https://www.jstor.org/stable/community.21320832>

Winkler, H. C. A. (1954). Clemens Winkler – Ein Lebensbild. In H. C. A. Winkler, A. Lissner, A. Lance, & R. Prokop, *Clemens Winkler. Gedenkschrift zur 50. Wiederkehr seines Todestages* (pp. 9-49). Berlin: Akademie-Verlag. Retrieved from <https://sachsen.digital/werkansicht/28667/9/0?cHash=859d3f7a2f3fb4a72855ee395386c598>

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This article has no conflict of interest