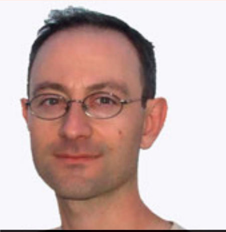

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# A feminine task:
## Karlik's and Bernert's discovery of the last natural occurring element

**KEYWORDS: Astatine, radioactive elements, missing and spurious elements, women in science.**

Abstract The conviction that knowledge acquired via scientific research could be out of the ordinary, or on a higher level, with respect to other forms of knowledge, whether artistic or cultural, was very deep-rooted among 20th century male scientists. At the same time, many scientists emphasized the objective character of their discoveries that allowed them access to an atmosphere of "reality" removed from value judgments and social ideologies, although this interpretation could also be debated. Perhaps "male Science" never held such a romantic position, nor its very name was always associated with the greatest opportunity and the highest ideals.
This paper takes into consideration the academic impact of Karlik and Bernert in their search for the last natural occurring element (astatine, Z=85) and it discusses pertinent topics, such as the increased number of discoveries in the nineteenth century due not only to female scientists working with their husbands (Curie and Noddack).

### THE ELUSIVE EIGHTY-FIFTH ELEMENT

From the 1920s into the 1950s, scientists tried a variety of techniques to locate element 85, the heaviest halogen, based on its presumed properties (1). The claimed discovery in 1931 at the Alabama Polytechnic Institute (now Auburn University) by Fred Allison (1882-1974) and associates, led to the spurious name for the element of *alabamine* (Ab) for a few years(2). This discovery was later shown to be one of the biggest scientific blunders of all time.
In 1937, at Dhaka university, the unknown radio-chemist, Rajendralal De, published the discovery of a pair of elements found in the mineral monazite, one of which was presumably *eka-iodine*, long sought after by chemists all over the world (3).
In the second half of the 1930s, other names attributed to this elusive element appeared. The presumed discoveries of Horia Hulubei (1896-1972) and Yvette Chaucois (1908-1999) of elements 87, 93, and 85 - observed by X-rays apparatus in the late 1930s - had as unique results the christens of these elements with the euphonious names of *moldavium*, *sequanium* and *dor* (4).
Soon after these facts Walter Minder (1905-1992), a Swiss radio-chemist, who received his degree in chemistry at Bern in 1930, quickly became interested in understanding the radioactive decay series of the thorium and uranium families. During 1936 he travelled to Berlin where he got in touch with the most renowned German atomic physicists of the time: Walther Bethe (1906-2005), Siegfried Flügge (1912-1997) and Carl Freidrich von Weizsäcker (1912-2007). In 1938 he was named assistant to professor Adolf Liechti (1898-1946) at the local Radium Institute of Bern hospital. That year he published his first article in which he hypothesized on the existence in nature of *eka-iodine* and *eka-cesium*. He also conducted tests to characterize halogens, after which, convinced of having discovered *eka-iodine* (5) wrote: "The beta-decay of Ra-A leads us certainly to hypothesize the formation of element 85. For this reason we suggest the name *helvetium*".
In 1942 Minder became acquainted with a young and beautiful English physicist, Alice Leigh-Smith, née Prebil (1907-1987). Alice Leigh-Smith approached Walter Minder and, exploiting all of her feminine charms, sought to convince him to re-locate to work with her German friends and colleagues in Berlin with the purpose of picking up important information on the status of atomic research in Germany (6). An analogous plan for the construction of an atomic bomb was advancing in great secrecy in the United States. The English, not having the same means of allying themselves with Americans, preferred to send a hugely remunerated spy to Berlin to discover the enemy's plans. Minder was not exactly enchanted with this proposition and refused to accompany Leigh-Smith. However, a strong bond grew between them anyway, culminating in their joint publication of their work in radiochemistry on December 26$^{th}$, 1942 (7). At the conclusion of their work, they both expressed a desire to name the 85$^{th}$ element: "As a tribute to the scientific work

of our two countries, we propose to name element 85 *anglo-helvetium*".
A bitter criticism to this work arrived from England in the form of a letter from the radiochemist F. A. Paneth (1887-1958). On May $23^{rd}$, 1942, he wrote(8): "There is so far no trustworthy indication of a branching of any of the main radioactive series leading to an element 85. Nor has a stable form of this element been found." Paneth's second criticism relative to the existence of stable isotopes of element 85 was addressed to Hulubei's spectroscopic work.
Shortly after Paneth's intervention a young Viennese radiochemist Berta Karlik and her assistant Gertrud Cless-Bernert came to the limelight, succeeding in discovery of the only natural isotope of element 85, but it soon turned out to be not the same one "identified" by Minder…

**KARLIK'S AND TAUSCHINSKI'S SEARCH FOR THE NATURAL ASTATINE ISOTOPES**

For several reasons, maybe in part because of the encouragement offered by Stefan Meyer (1872-1949), the head of the institute, and in part because the boundary between chemistry and physics had been more open to women physicists, the *Institut für Radiumforschung* became a *mecca* for women exploring the complex of the fields surrounding nuclear physics, radio-chemistry, and radio-physics. Meyer brought in, among others, Berta Karlik and Marietta Blau (1894-1970); the former was able to co-author paper with Gertrud Cless-Bernert, the latter was able to supervise the dissertations of at least five other women, in the years 1930-1937: Elizabeth Rona (1891-1981), Elisabeth Kara-Michailowa (1897-1968), Hertha Wambacher (1903-1950), Stefanie Zila, and Elvira Steppan.
Berta Karlik was born in Vienna on January $24^{th}$ 1904, eldest of three children of Carl Karlik, director of the *Landeshypothekenanstalt* of Lower Austria, and Karoline née Baier. In her infancy Berta enjoyed private lessons, but later she attended public school in Mauerbach. In the summer 1923, she graduated with distinction. She entered the University of Vienna and on October $10^{th}$ 1927 she discussed her thesis, under the tutorage of Stefan Meyer: "Über die Abhängigkeit der Szintillationen von der Beschaffenheit des Zinksulfides und das Wesen des Szintillationsvorganges" (9).

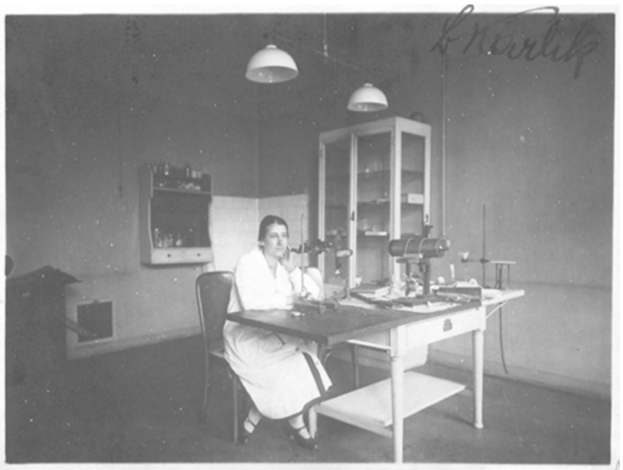

**Figure 1.** Berta Karlik at the Radium Institute in Vienna, 1920s.

On March $8^{th}$ 1928 she obtained her Ph.D. "*Philosophiae Doctor*" at the University of Vienna.
From November 1930 to December 1931 she worked at the Royal Institution of Great Britain in London, headed by Nobel laureate Sir William Bragg (1890-1971), during which period her researches were focuses on X-ray studies of crystal structures.
Berta Karlik took advantage of the time she spent in England and visited a large number of physical, chemical and biological Institutes. She had several opportunities to stay for a long time at the Cavendish Laboratory in Cambridge, which was led by Lord Rutherford (1871-1937), the famous pioneer in the field of nuclear physics. She could become familiar with this institution and in particular with the radioactive research and devoted herself, while in London, studying the medical application of radium, also attending the physical divisions of six leading hospitals.
In summer 1931 she travelled from London to Paris and she visited the laboratory of Louis de Broglie (1892-1987), the Pasteur Institute and the Curie Institute, where she personally met the legendary figure of Madame Curie (1867-1934).
When eventually she came back to Vienna she dedicated her scientific research at the *Radiumforschung*. On April $1^{st}$ 1933 Berta Karlik was appointed graduate assistant. In 1937 she received the *Venia Legendi* of physics at the University of Vienna and two years later she was appointed lecturer. In October 1940 she was appointed research assistant at the Institute for Radium Research.
During the World War II, she and her colleague Traude Cless-Bernert succeeded in collecting a very significant discovery: they managed to close the last gap in the periodic table of the elements. In autumn 1944 heavy bombardments of Vienna began. Alongside the valuable equipment of the Institute and radium stocks were brought to safety outside Vienna, and the hunt for element 85 had a sudden stop.
However this work was, for Karlik alone, crowned with the 1947 "Haitinger Prize" for chemistry with the following motivation: *Frau Karlik ist durch die Entdeckung des Elements 85 in die Namen der Gelehrten von internationalem Ruf eingetreten.*
Her boss and mentor professor Gustav Ortner died in late April 1945. Under the difficult conditions due to war, Berta Karlik, was requested by the Academy of Science to take the provisional directorship of the Institute for Radium Research. She reported in her diary: "Als im April 1945 Wien zum Kriegsschauplatz wurde, tobte der Kampf einige Tage hindurch auch in der unmittelbaren Umgebung des Instituts. (…), das Radiuminstitut kam glücklicherweise ohne größeren Schaden davon. (…) Es bot einen traurigen Anblick: Die leeren Räume waren bedeckt mit Glasscherben und Schutt und Staub, der von Bombentreffern der Umgebung hereingeschleudert worden war"(10).

In 1950 Berta Karlik was appointed associate professor and later full professor (*ordentliche Professor*), position never reached before by a woman in Austria. In 1954 Berta Karlik became a corresponding member of the Austrian Academy of Sciences. When on September $1^{st}$ 1974 the Faculty of Science asked Berta Karlik to retire she replied "yes", with the condition that professor Dr. Herbert Vonach could be her successor the next day.
On February $4^{th}$ 1990 having just turned her $86^{th}$ birthday, Berta Karlik died peacefully in her home. Vonach Herbert wrote her obituary in which he stated: "Eine ganze

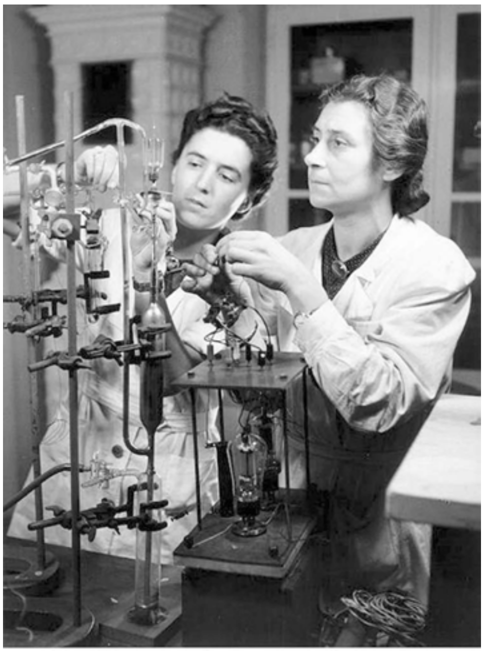

**Figure 2.** Berta Karlik (right) and Gertrud Cless-Bernert (left) in their laboratory, 1942.

Generation von Physikern wurde von ihr in die Welt der Atome und Kerne eingeführt(11)".

The life of Gertrud Tauschinski (born in Vienna on June 27th 1915), Karlik's assistant, gave so much less satisfaction and professional recognition than that of her boss. She graduated on June 22nd 1933; later she expressed the desire to study architecture at the Technische Hochschule but before the end of winter semester she left her architecture studies for physics at Vienna University. In 1938, one year previous her promotion, she spent a semester in Leipzig. Eventually she discussed her thesis on July 12th 1939 under the supervision of professors Gustav Ortner (1900-1945), Eduard Haschek (1875-1947) and Egon von Schweidler (1873-1948) at the *Radiuminstitut*.

In 1940 Gertrud Tauschinski married Mr Bernert from which she had a son. She occupied the position of "volunteer assistant" at the *Institut für Radiumforschung*, and there she had the opportunity to work closely with Dr. Berta Karlik eleven years her senior. Together they found the natural isotope of element 85. In 1945 she was appointed as laboratory technician at the same Institute and later she spent one year (1948-49) in Sweden, but her "finest hour" in scientific research of high level was fatally fading away. Since 1959 she was appointed "scientific secretary" for the *Konferenz Atoms for Peace* at Geneva. Later she became a salaried consultant for industrial applications of isotopes. In 1961 she married for the second time with the engineer F. Cless. Her hopes and plans of future work were soon frustrated by an accident that forced her to retire early. Gertrud Cless-Bernert née Tauschinski died on 20th February 1998. Although she was four months short of her 83rd birthday, her death was regarded by friends and relatives as sudden as unexpected. Coming back to the history of the discovery of element 85, Berta Karlik and Traude Bernert observed the alpha particle emissions of $^{218}$At as early as 1942. The experiments of Minder and Leigh-Smith were repeated by Karlik and her colleague Traude Bernert, but they did not observe the weak beta radiation that Minder and Leigh-Smith claimed was characteristic of *anglo-helvetium*. Karlik considered the work of the two Bern physicists as the height of error. Using a methodology totally different from that used to "discover" *anglo-helvetium*, Berta Karlik discovered the short-lived natural isotope of *eka-iodine* ($^{218}$At) with a half-life of about two minutes.

In 1943, Karlik and Bernert were working with an intense sources of RaA ($^{218}$Po). RaA preparations were made by electronic activation and short exposure (10-15 seconds) of $^{222}$Rn (~100 milliCurie) and immediately tested by a 4-stage tube electrometer and oscillograph for α-rays of range beyond these of RaA. Successively, a second group of RaC› rays was found, originating a very α-unstable isotope of mass number 218 ($^{218}$85). The range of the new α-ray was 5.53 cm, with the energy of 6.63 meV, and a half life of about 2 seconds(12). The amounts of β-decompositions *per* α-decomposition for RaA (in other words, the *ratio* of "element 85" and RaC' formed from RaA) was found to be $3.3\times10^{-4}$.

The following year, while the face of German and Austrian cities was drastically altered by the Anglo-American bombing, Berta Karlik and Traude Bernert found that the new α-rays (13) in the thorium and actinium series corresponded to the isotopes $^{216}$85 and $^{215}$85. Besides in contrast to the results of Minder, the β-activity of RaA was in agreement with theoretical predictions. With RaA a group of α-particles of range 5.53 cm was found and attributed to isotope 218 of element 85. Similar observations with thorium emanation and actinium emanation were related to isotopes 216 and 215 of element 85. These isotopes fit-in well in curves of disintegration energy *vs.* mass number. Good agreement was also found for the energy balance of the Ra series, while for the Th and Ac series a hypothesis of isomeric nuclei was proposed although with some difficulties (14).

This element occurs in the natural decay chains as a result of product after with very low branching ratio taking place β-decay of Ra (218Po), ThA (216Po) and AcA (215Po); Karlik and Bernert observed the radiation of the formation and decay of that isotope (mass 218) of element 85 and were able to demonstrate that it appeared at the uranium-radium series. However, other researchers in the USA had induced nuclear reactions and produced artificially this item in 1942 previously – exactly two years earlier than Karlik and Bernert.

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actinium chain | | | | | | | | | | Th-231 25.6h | ← α β⁻ | U-235 $7\times10^8$y |
| | | | | | At-219 0.9 m | ← | Fr-223 22 m | ← | Ac-227 22 y | ← α β⁻ | Pa-231 $3.3\times10^4$y | |
| | | Pb-211 36.1m | ← α β⁻ | Po-215 1.8ms | ← α | Rn-219 3.9s | ← α | Ra-223 11.4d | ← α | Th-227 18.7d | | |
| | Tl-207 4.8m | ← α β⁻ | Bi-211 2.15m | | | | | | | | | |
| | | Pb-207 stable | | | | | | | | | | |

**Table 1.** The actinium (4n + 3) series runs from uranium 235, via actinium 227, to lead 207.

They synthesized element 85 and in the mean time they were recognised as the true discoverer of it; Karlik and Bernert, who had identified a natural isotope of element 85 - despite the immense credit for this success - did not come right of naming it. They would have chosen the name *Viennium*(15). Later researchers in the United States called the element Astatine. In the fall of 1944, heavy allied bombardment of Vienna began. The valuable equipment of the Institute and the radium stocks were brought to safety outside city and the two women abruptly had to interrupt their radiochemical researches.

Astatine (At) has 37 known isotopes, all of which are radioactive; the range of their mass numbers is from 191 to 229. There also exist 23 metastable excited states. The longest-lived isotope is $^{210}$At, which has a half-life of 8.1 hours; the longest-lived isotope existing in naturally occurring decay chains is $^{219}$At with a half-life of 56 seconds (16). Actinium-219 was chemically separated from a natural source only in 1953 by Earl K. Hyde (1920-1997) and Albert Ghiorso (1915-2010)(17). However the accepted proof of element 85's existence came in 1940 from the Berkeley group of Dale R. Corson (1914-2012), Kenneth R. MacKenzie (1912-2002), and Emilio Gino Segré (1905-1989), who synthesized the element by alpha particle bombardment of bismuth (18). The turmoil of World War II and the fundamental question of artificial *vs.* natural elements, leads to the delay of the discovery credit and the honor of naming the element until 1947 (19).

## CONCLUSION

It is well consolidated that the difficulties facing women scientists are deep-rooted. It is not a personal speculation that in the late nineteenth century and in the first decades of twentieth century there were almost no initiatives to support them in their academic careers. And, in some Country, in addition to these considerable barriers, their admission to the University was banned.

Berta Karlik worked for the University of Vienna and eventually become the first female professor at that institution. She discovered that the element 85, astatine, is a product of the natural decay processes, after several scientists in vain searched for it in radioactive minerals. Berta Karlik was not the only chemist influenced by her mentor but, she was one of those who, without marrying him, took his direction seriously enough to influence other women in research, high in quality.


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## REFERENCES AND NOTES


1. Fontani, M., Costa, M. DE REDITU EORUM, Sulle tracce degli elementi scomparsi, (2009), Società chimica italiana Ed., Roma, 359-69. Fontani, M., Costa, M., Orna M.V. THE LOST ELEMENTS: THE PERIODIC TABLE'S SHADOW SIDE, (2014), Oxford University Press, Hardcover, 576 Pages, 55 pictures.
2. Allison, F., Murphy, E. J., Bishop, E. R. et al. "Evidence of the Detection of Element 85 in Certain Substances," *Physical Reviews*, 37(9), 1178-80, (1931). Allison, F., Bishop, E. R., Sommer, A. L. , "Concentration, Acids and Lithium Salts" of Element 85," *J. Am. Chem. Soc.*, 54, 616-620, (1932).
3. Das, A., De, R., *J. Indian Chem. Soc.*, 13, 197, (1936). De, R., "Twin Elements in Travancore Monazite", *Separate* (Bani Press, Dacca), 18, (1937). De, R., *Indian Journal of Physics*, 13, 407, (1939). R. De, "New Elements in Monazite Sand", *Sri Gouranga Press*, Calcutta, 21, (1947).
4. Hulubei, H., "Recherches relatives à l'élement 87", *Compt. Rend.*, 202, 1927-29, (1936). Hulubei, H., *Compt. Rend.*, 205, 854, (1937). Hulubei, H., Cauchois, Y., "Spectres de l'émission propre ondulatorie du radon et de ses dérivés. Raies attribuables à l'élément 85," *Compt. Rend.*, 209, 39-42 (1939). Hulubei H., "Sur L'Element 85", *Bull. Section Scientifique de l'Academie Roumaine, 27*, 124-134 (1944). Hulubei H.,, "État Actuel des Informations Sur Les Isotopes de Numéro Atomique 85," *J. Chim. Phys. Phys.-Chim. Biol., 44*, 225-229, (1947).
5. Minder, W., "Über die β-Strahlung des Ra A und die Bildung des Elementes mit der Kernladungzahl 85", *Helvetica Physica Acta*, 13, 144-152, (1940).
6. Minder, W., *Gheschichte der Radioaktivität*, Springer Ed., (1981).
7. Leigh-Smith, A., Minder, W., "Experimental Evidence of the Existence of Element 85 in the Thorium Family", *Nature*, 150, 767-8, (1942).
8. Paneth, F. A., *Nature*, 149, 565, (1942).
9. "On the dependence of scintillations on the nature of the zinc sulphide and the essence of scintillation process"
10. When in April 1945, Vienna was the set of war, the battle raged for several days passed in the immediate vicinity of the institute. (...), the Radium Institute fortunately was not seriously damaged. (...) I provided a sad sight: The empty spaces were covered with broken glasses and rubbles and dust provoked by the bombs.
11. A whole generation of physicists was introduced by her into the world of atoms and nuclei.
12. Karlik, B., Bernert, T., "Eine Neue Natürliche α-Strahlung", *Naturwissenschaften*, 31, 298-99, (1943). Karlik, B., Bernert, T., "Ein Weiterer Dualer Zerfall in der Thoriumreihe," *Naturwissenschaften*, 31, 492, (1943). Karlik, B. Bernert, T. "Über eine dem Element 85 Zugeordnete α-Strahlung", *Sitzber. Akad. Wiss. Wien, Math.-naturw. Klasse*, 152, 103-110, (1943).
13. Karlik, B., Bernert, T., *Anz. Akad. Wiss. Wien, Math.-naturw. Klasse*, 81(No. 1), 2, (1944). Karlik, B., Bernert, T., "Das Element 85 in der Actiniumreihe," *Naturwissenschaften, 32*, 44, (1944).
14. Karlik, B., Bernert, T., "Das Element 85 in den Natürlichen Zerfallsreihen", *Zeitschrift für Physik*, 123, 51-72, (1944).
15. Strohmaier B., Österreichischer Verband für *Strahlenschutz*, "Berta Karlik (1904–1990) Kernphysikerin, Wissenschaftsmanagerin, erste Ordinaria an einer philosophischen Fakultät in Österreich", 42(1), 20-29, (2008).
16. Audi, G., Wapstra, A. H., Thibault, C. et al. "The Nubase evaluation of nuclear and decay properties", *Nuclear Physics A*, 729, 3–128, (2003).
17. Hyde, E. K., Ghiorso, A., "The α-branching of Ac K and the presence of astatine in nature", *Phys. Rev.*, 90, 267, (1953).
18. Corson, D. R., MacKenzie, K. R., "Artificially Produced Alpha-Particle Emitters," *Phys. Rev.*, 57, 250, (1940). Corson, D. R., Mackenzie, K. R., Segré, E. G., "Possible Production of Radioactive Isotopes of Element 85" , *Phys. Rev.*, 57, 459, (1940). Corson, D. R., Mackenzie, K. R., Segré, E. G., "Some Chemical Properties of Element 85" , *Phys. Rev.*, 57, 1087, (1940). Corson, D. R., Mackenzie, K. R., Segré, E. G., "Artificially Radioactive Element 85" , *Phys. Rev.*, 58, 672-78 (1940). Corson, D. R., "Astatine," *Chem. Eng, News*, 81, 158, (2003).
19. Corson, D. R., Mackenzie, K. R., Segré, E. G., "Astatine: Element of Atomic Number 85" , *Nature*, 159, 24, (1947).