Foundations of Chemistry (2023) 25:235–251
https://doi.org/10.1007/s10698-022-09452-9

ORIGINAL PAPER

Name game: the naming history of the chemical elements—part 3—rivalry of scientists in the twentieth and twenty-first centuries

Paweł Miśkowiec[1]

Accepted: 16 October 2022 / Published online: 12 November 2022

Abstract
The third article of the "Naming game…" series presents the issues of naming elements discovered and synthesized in the twentieth and twenty-first centuries. Based on the source data, the publication time of the names of the last 35 chemical elements was identified. In the case of discoveries from the end of the twentieth century and the beginning of the twenty-first century, the principle was adopted of the priority of information about the synthesis of a new chemical element in scientific journals or conference reports. However, when the same information was published earlier in the news sections of scientific journals, in articles in popular science journals, and (in modern times) on the websites of interested research institutes, such an info is presented as well. It turned out that in some cases this information is very complex as the names of some elements were changed several times and published in different media in the same period. Therefore, this article is an attempt to sort out the issue of first publishing of the names of the last known 35 chemical elements.

Keywords Chemical elements · Naming history · History of chemistry · Radioactive elements

Introduction

By the beginning of the twentieth century, all elements with stable isotopes had already been discovered. The last 4 were discovered and named until 1925. Therefore, the twentieth and twenty-first centuries can be called the centuries of unstable—radioactive elements in terms of discoveries, synthesis and nomenclature. The described period can be divided into the following (overlapping) stages: discovery of the last elements with stable nuclei, discovery of elements with unstable isotopes (protactinium, francium), and finally the synthesis of elements – first those that can still be detected in the environment, and then the synthesis of elements artificial—not naturally occurring. The syntheses were possible

✉ Paweł Miśkowiec
p.miskowiec@uj.edu.pl

[1] Department of Environmental Chemistry, Faculty of Chemistry, Jagiellonian University, Gronostajowa 2, 30-387, Krakow, Poland

because of the invention of the cyclotron in 1932. Thanks to this, physicists also entered the stage of elements' naming.

From europium to oganesson—nomenclature history of twentieth and twenty-first century

The following paragraphs discuss 35 chemical elements discovered and named in the nineteenth century. The discussed elements are distinguished in the periodic table of elements in Fig. 1.

Two last stable rare earth elements—europium and lutetium

Europium

The discovery of europium is credited to Eugène Anatole Demarçay, who already in 1896 suspected that samples of samarium were contaminated with an unknown element and isolated it in 1901. He named the new element europium in the note: *Sur un nouvel élément l'europium* published in *Comptes rendus hebdomadaires des séances de l'Académie des sciences* (Demarçay 1901). Thus, europium was the first element described and named in the twentieth century.

Lutetium

Lutetium was the last discovered stable rare earth metal. It was separated from "ytterbia" by Georges Urbain in 1907. The new discovery was named "lutecium" and described in the paper *Un nouvel élément: le lutécium, résultant du dédoublement de l'ylterbium de Marignac* printed in *Comptes rendus hebdomadaires des séances de l'Académie des sciences*

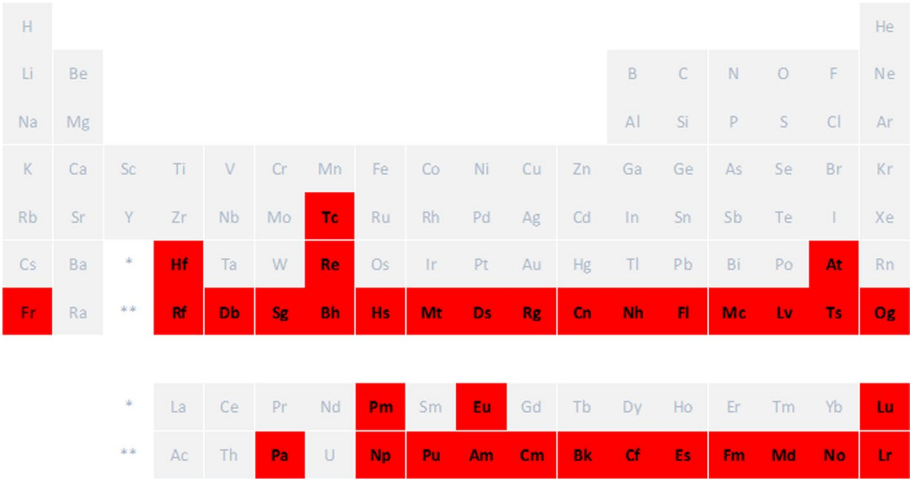

Fig.1 Elements discovered, synthesized and named in twentieth and twenty-first century

(Urbain 1907). In 1949 IUPAC changed the name of the element #71 into lutetium (Koppenol 2005).

Protactinium

Protactinium was discovered and named at least twice. First time in 1913, by Kasimir Fajans and his assistants Paul Beer and Otto Göhring, who called it "brevium" due to the short half-life of the studied isotope ^{234} Pa (Fajans and Beer 1913; Fajans and Göhring 1913). However, 5 years later Otto Hahn and Lise Meitner duet (and independently Frederick Soddy and John Cranston) discovered more stable isotope of this element and named it protactinium *(*not *protoactinium*, as suggested in many sources*)*. The discovery and the name were presented by Hahn and Meitner in *Physikalische Zeitschrift,* in the article *Die Muttersubstanz des Actiniums, ein neues radioactives Element von Langer Lebensdauer,* as well as by Meitner in *Zeitschrift für Elektrochemie und angewandte physikalische Chemie* under the same title (Fajans and Morris 1973; Meitner 1918; Meitner and Hahn 1918; Sime 1986; Soddy and Cranston 1918).

Hafnium

The story of searching and naming the element #72 is complex and full of tensions between scientists (Fernelius 1982; Scerri 2013). Finally it was Dirk Coster and Georg von Hevesy who managed to confirm the discovery of a new element in zircon mineral in 1922. The first announcement of the discovery was unusual, as Niels Bohr mentioned it in his Noble lecture in Stockholm on December 11th in 1922 (Bohr 1922). The first note with proposal of name "hafnium" was published in January 1923 in *Nature* in the letter entitled *On the Missing Element of Atomic Number 72* (Coster and Hevesy 1923). Assuming the discovery of rhenium took place in 1908, hafnium was therefore the last stable element to be discovered.

Rhenium

In 1908 Masataka Ogawa announced the discovery of the element #43, which he named "nipponium"(Ogawa 1908). The Ogawa's results were later called into question because the experiment could not be repeated. However, the recent analysis of the discovery depicted that he in fact discovered the element #75 (Yoshihara 2004). Due to Ogawa's mistake the discovery of the element #75 was credited to Walter Noddack, Ida Tacke, and Otto Berg, who detected a new element in platinum ore, columbite and some other minerals. They announced their discovery and the element name proposal in the article *Die Ekamangane,* published in *Naturwissenschaften* in 1925 (Noddack et al. 1925).

Francium

Francium was the last element found in nature before it was synthesized. The element was discovered by Margaret Perey in 1939. She published her discovery, naming the new element "actinium K" (Perey 1939a, b). On March 21st, 1946 she defended her doctoral thesis entitled *L'élément 87: Actinium K* (Perey 1946a). In the last line of the work one reads: "The name Francium, Fa, is proposed for box 87" (Adloff and Kauffman

2005; Preston 2018). Based on her thesis three articles were published in the *Journal de Chimie Physique* in 1946 (Perey 1946b, c, d). The name proposal appeared at the end of the second paper:*"Propriétés chimiques de l'élément 87: actinium K"*. However, it should be noted that the nomenclature proposal, presented in the above mentioned article, sounded slightly ambiguously, as if Perey wanted to keep the name "actinium K" and symbol AcK for the result of the actinium decay (according to the tradition of that time), but at the same time to call it "francium" in order to put that name in a vacant place #87 in the periodic table of elements. Namely, Perey wrote: "I propose to leave to the first element 87, derived from actinium, whose physical and chemical properties have just been described, the name of actinium K AcK, but to give to box 87 the name Francium with symbol Fa" (Perey 1946c).

The synthesized elements

The following five elements (Tc, At, Pm, Np, Pu) were artificially synthesized before being found in nature, as their abundance is extremely low, due to the lack of stable isotopes. What they have in common is the fact that the discoverers did not immediately suggest the names. One of the reasons was the difficult period of the World War II, when the nuclear discoveries were kept in secret, another one was that an element created synthetically in practically invisible quantities, that had not yet been discovered in nature, was not seen as a completely valid one, especially if it was an unstable radioactive isotope. The situation changed in 1947, after publishing of the article in *Nature* by one of the most recognizable chemists of that time—Friedrich Paneth. He managed to establish a new order in the chemical nomenclature—regarding both naming of isotopes and the procedure of naming the new elements, including those man-made. In the paper entitled *The making of the missing chemical elements* he called to finally recognize synthetic elements and asked his colleagues "creators-discoverers" of the still unnamed elements to name them (Koppenol 2005; Paneth 1947).The moment of artificial synthesis of the first element in the cyclotron also symbolically marks the moment when physicists enter the scene of discovering subsequent elements of the periodic table.

Technetium

Technetium was the first element produced artificially. Element 43 was first obtained by Perrier and Segre in 1937 by bombarding molybdenum with deuterons or with neutrons in cyclotron. They announced their discovery in the meeting of the Reale Accademia Nazionale dei Lincei on 4 June 1937. The communication was read under the title *"Alcune proprieta chimiche dell'elemento 43"* and subsequently published under the same title in the *Rendiconti della Reale Academia Nazionale dei Lincei* (Perrier and Segré 1937). The international announcement appeared in Nature on July 31, 1937 (De Jonge and Pauwels 1996; Perrier and Segrè 1937). However, they officially named the new synthesized element not earlier than ten years later, in the article *Technetium: The Element of Atomic Number 43,* published in *Nature* (Perrier and Segrè 1947). In 1961 Kenna and Kuroda reported the first isolation of natural isotope of technetium ^{99}Tc in Belgian Congo pitchblende as a result of natural fission of ^{238}U (Kenna and Kuroda 1961).

Astatine

Astatine was discovered in 1940. Dale Corson, Kenneth Ross MacKenzie, and Emilio Segrè isolated the element by its creation. They bombarded ^{209}Bi with α particles in a cyclotron to produce synthetic ^{211}At (Corson et al. 1940). They named the element in 1947, publishing the note *Astatine: The Element of Atomic Number 85* in the periodical *Nature* (Corson et al. 1947). Regardless of the research in Berkeley, the search for element #85 in nature was carried out. It turned out that it may be formed in trace amounts in natural decay chains. The first confirmed report of the discovery of natural astatine was published in 1943 in *Die Naturwissenschaften* by the duo Berta Karlik & Traude Bernert (Karlik and Bernert 1943). However, according to modern studies, it is probable, that the spectral lines of astatine may have been observed by Hulubei and Cauchois already in 1939 (Hulubei and Cauchois 1939; Thornton 2010).

Promethium

Promethium was the final lanthanide to be discovered. In 1945 Jacob Marinsky, Lawrence Glendenin and Charles Coryell acquired its undeniable evidence. They worked for the Manhattan Project at Oak Ridge and identified ^{147}61 in the by-products of uranium-235 fission. They announced their discovery in 1947 in the *Journal of the American Chemical Society,* but no name was proposed at the time (Marinsky et al. 1947). The official name proposal first appeared in 1948 in *Chemical & Engineering News Archive* in the note *A Proposal of the Name Prometheum for Element 61*(Marinsky and Glendenin 1948). In 1950, the International Atomic Balance Commission gave the modern name "promethium" to the element 61 (Elkina and Kurushkin 2020).Traces of promethium were found for the first time in nature by Olavi Erämetsä in 1965, who separated out ^{145}Pm from a rare earth concentrate (Erämetsä 1965).

The "War elements": Np, Pu, Am, Cm

Neptunium, plutonium

The first transuranium element was observed and isolated in 1940 by scientists from Berkeley: Edwin McMillan and Philip Abelson, in fission products of uranium-238, although some scientists credit the team of Enrico Fermi with the earlier discovery of the element #93—already in 1934 (Fermi 1934; Sime 2000). Scientist from Berkeley announced their discovery in the paper *Radioactive Element 93* in the *Physical Review,* but they did not propose the name (McMillan and Abelson 1940). They soon decided to name it neptunium. In 1941 Glenn Seaborg, together with Arthur C. Wahl and Joseph W. Kennedy, produced and identified the second known transuranium element, plutonium (atomic number 94). However, all the reports from 1941–1945 about newly discovered radioactive elements became classified due to secrecy about nuclear reactions and were not published until the end of 1945. Therefore it is extremely difficult to determine the moment of revealing of the first information about the element names to the public. It is worth emphasizing that even in the declassified technical reports of June

1942 concerning, among others, of these elements, their names do not appear, but only their atomic numbers (Kennedy et al. 1942).

Officially, the history of discovery of elements 93 and 94, including the origin of their names, was announced by Glenn T. Seaborg at the *Technical Conference of the Chicago Section of the ACS at Northwestern University*, on November 16, 1945. His announcement was printed in *Chemical & Engineering News* under the original title *The Chemical and Radioactive Properties of the Heavy Elements* on December 10 (Seaborg 1945). A few days earlier, his announcement about the discovery of subsequent elements #95 and #96, with an annotation about plutonium-239, was printed in *Science* (Seaborg and Hamilton 1945). However, the information about new elements had been made public at least a few months earlier, after dropping atomic bombs by US on Hiroshima and Nagasaki in August 1945. According to the author's best knowledge, the first popular-science (excluding daily newspapers) information about both the atomic bombs and two transurans (neptunium and plutonium) can be found in a series of three notes in *The Science News-Letter* from 18th August 1945, entitled: a) *Rapid Assembling, b) Idea for Plutonium Bomb Credited to Dr. Lawrence* and *c) Made to Order* (The Science News Letter 1945a; The Science News Letter 1945b; The Science News Letter 1945c). It should be noted that plutonium was found in nature by Glenn Seaborg and Morris Perlman already in 1942, but their research was classified as well and not published until 1948 in JACS (Seaborg and Perlman 1948). Small quantities of neptunium were found in nature for the first time in 1952 (Peppard et al. 1952).

Americium, curium

The production of elements #95 and #96 in 1944 by the group of Glenn T. Seaborg from Berkeley was classified and only released to the public in November 1945. Officially, the discovery was announced by Glenn T. Seaborg at the already mentioned *Technical Conference of the Chicago Section of the ACS at Northwestern University*, on November 16, 1945, and his announcement was printed in the above cited papers, in *Science* and *Chemical & Engineering News,* but no name was proposed (Seaborg 1945; Seaborg and Hamilton 1945). Unofficially, Glen Seaborg unveiled the secret of the discovery of elements #95 and #96 unintentionally, during the radio broadcast for children called Quiz Kids on November 11 1945 (Still 2017). Finally, the names americium (#95) and curium (#96) were suggested by Glenn Seaborg at the annual *Spring Meeting of the American Chemical Society* in Atlantic City on April 10, 1946, and published in *Chemical and Engineering News* on May 10, 1946, under the title *The Impact Of Nuclear Chemistry* (Seaborg 1946). However, once again the first mention of the names of new elements had been printed three weeks earlier in *Science* on 19th of April 1946, in the chapter *U. S. News and Notes* (Science 1946).

Berkelium

Element 97 was first intentionally synthesized and identified in December 1949 in Berkeley by Glenn T. Seaborg, Albert Ghiorso and Stanley G. Thompson. They announced the new discovery in the letter to editor in the March issue of the *Physical Review,* entitled *Element 97* (Thompson et al. 1950a). However, similarly to the case of previous transuranes, the first short note about new element had already been published in January 1950 in *The Science News-Letter,* under the title *No. 97 Dubbed Berkelium* (The Science News Letter 1950a).

Californium

Californium was at first synthesized at the beginning of 1950 by the team from Berkeley. They announced the new discovery in the letter to Editor of the *Physical Review* in the May issue, entitled *Element 98* (Thompson et al. 1950b).In this case, again, the first short note about new element and its name proposal had already been published in March 1950 in *The Science News-Letter,* under the title *Californium Element 98* (The Science News Letter 1950b).

Einsteinium, fermium

Einsteinium and fermium were discovered in 1952 by the team from Berkeley in the debris from the explosion of the first successful test of a hydrogen bomb "Ivy Mike". The discovery of new elements was, however, kept secret until 1955 due to Cold War tensions. Finally, the article was published almost three years after the discovery, in August 1955, in *Physical Reviews* under the title *New Elements Einsteinium and Fermium, Atomic Numbers 99 and 100* (Ghiorso et al. 1955b).

Mendelevium

Mendelevium was synthesized in 1955 in Berkeley—3 years after the discovery of einsteinium and fermium, but the element´s name was published slightly earlier then the names of two previous ones. The letter of the Berkeley team was published in *Physical Review* in June 1955, under the title *New Element Mendelevium, Atomic Number 101* (Ghiorso et al. 1955a). However, already in May 1955 there was a short note about the discovery (including the name) of mendelevium in *The Science News-Letter,* entitled *Element 101 Discovered* (The Science News Letter 1955).

Nobelium and the transfermium wars

At least three groups of researchers claimed to have synthesized and detected the element 102. The first one—international—from the Argonne National Laboratory, USA, the Harwell Atomic Energy Research Establishment, England and the Nobel Institute of Physics, Sweden, the second one from Berkeley (Lawrence Radiation Laboratory) and the third one—Joint Institute for Nuclear Research (JINR) in Dubna, USSR. The first group published their results in *Physical Review* in 1957 and proposed the name nobelium in the note *Production of the New Element 102* (Fields et al. 1957). Again, the short note (including the name proposal) about the discovery had been published slightly earlier in *The Science News-Letter* in July 1957, under the title *Make New Element 102* (The Science News Letter 1957). The proposed name was immediately recognized by IUPAC. However, the American and Soviet groups did not manage to repeat the experiment, so the claiming priority to the international group by IUPAC turned out to be premature. The Berkeley team claimed to have synthesized element 102 two years later, but decided to keep the name. The Soviet team questioned the discovery of

Americans and Swedes, announcing that it was the group from Dubna who conclusively synthesized the element 102 between 1963 and 1966 and named it "joliotum".

The Soviet naming declaration created an element naming controversy manifested by the mutual lack of recognition of the discoveries of successive super-heavy elements by rival groups of scientists. This period in the history of the discovery of elements is called the transfermium wars. Conflicts were not resolved for several decades till the late 90's, when IUPAC and IUPAP started to cease the fire. The controversy about the naming was complex, there were no strict rules about recognizing the priority of naming, as scientists started to synthesize new elements instead of their discovering. However, the presentation of the history of these changes in nomenclature goes much beyond the scope of the article, therefore only the short information and the articles with proposals of new elements' names accepted nowadays are presented. Readers interested in detailed history of naming, renaming, and compromises in naming of the elements #102–#110 may read about them elsewhere (Cartlidge 2018; Kragh 2018; Robinson 2021).

Lawrencium

The name Lawrencium was proposed by the group from Berkeley in 1961. The article entitled *New Element, Lawrencium, Atomic Number 103* was published in May 1961 in the *Physical Review Letters* (Ghiorso et al. 1961). The short note about the discovery had already seen the daylight in April 1961 under the title *Element 103 Created and Identified by Berkeley Research Group* in the section *News Notes* of the periodic *Science* (Science 1961).

Ruthefordium

The element #104 was first detected by Soviet team from Dubna in 1964 (Flerov et al. 1964) and named "kurchatovium", but it was the American proposal of the name ruthefordium that was finally ratified by the IUPAC Council meeting in 1997 (IUPAC 1997). The names of the elements #104 and #105 were in general the biggest bones of contention among scientists and changed most often during the period of transfermium wars. The first time officially name ruthefordium appeared in the second note about American detection of the element #104 in 1970, under the title *261Rf; new isotope of element 104* published in *Physics Letters B* (Ghiorso et al. 1970a).

Dubnium

In 1968 scientists from JINR obtained isotope of the element #105. This experiment was published at the beginning of 1971 in the *Nuclear Physics A* (Flerov et al. 1971).Surprisingly, a name of the element was not proposed in the report. Meanwhile, the American group also observed element #105, but in a different reaction. Thus, they named the element "hahnium" (Ghiorso et al. 1970b). The naming controversies lasted till 1997, when the compromise about the elements 101–109 was finally proposed and accepted by the main players—scientists from the USA, Russia and Germany. The IUPAC recommended the name dubnium for the element #105 in the announcement published in *Pure and Applied Chemistry* entitled *Names and symbols of transfermium elements (IUPAC*

Recommendations 1997) and this was in fact the first official assignment of this name to this particular element (IUPAC 1997).

Seaborgium

The element #106 was synthesized in 1974 both by Russians and Americans (Ghiorso et al. 1974; Оганесян et al. 1974). However, the naming controversy lasted for more than twenty years. In this case it was not only the question of a priority, but also of the honoring of a living person—Glenn Seaborg (Rayner-Canham and Zheng 2008). The name was not proposed until so called Transfermium Working Group recognized the American group as the official discoverers in 1993 (Barber et al. 1993). The proposal of the name "seaborgium" was announced at the *207th National Meeting of the American Chemical Society* in San Diego in March 1994. The announcement results in the short notes in *Science News* from March 19th (*Element 106 Takes the Name Seaborgium)* and in *Chemical & Engineering News* from March 21st (*Element 106 name to honor Glenn Seaborg)*, which are in fact the first notes about seaborgium (Lipkin 1994; Dagani 1994). The name was finally widely recognized and accepted in 1997 (IUPAC 1997).

Bohrium,

The element #107 was synthesized without much controversy by Gottfried Münzenberg and his co-workers from the Centre for Heavy Ion Research in Darmstadt in 1981 (Gesellschaft für Schwerionenforschung—GSI) although the Soviet team had claimed the synthesis five years earlier, which was unconfirmed by other groups (Münzenberg et al. 1981; Oganessian et al. 1976). Germans first proposed the name "nielsbohrium", however, IUPAC finally proposed (and somewhat imposed) the name bohrium. This proposal was primarily published in *Pure and Applied Chemistry* in 1994 in the paper entitled *Names and symbols of transfermium elements (IUPAC Recommendations 1994)* (IUPAC 1994).

Meitnerium, hassium

Elements #109 and #108 were synthesized in Darmstadt in 1982 and 1984 respectively (Münzenberg et al. 1984, 1982). The original German proposals of their names—meitnerium and hassium respectively were finally accepted by IUPAC and other competing groups after the confirmation of the discovery priority. Those proposals were revealed for the first time in 1993, in the article published in *Progress in Particle and Nuclear Physics,* entitled *Response to the report of the transfermium working group* (Armbruster et al. 1993).

The synthesis of new elements in the era of information boom and the development of the internet

Ten years gap between elements synthesis performed after the element #108 and the finish of the Cold War resulted in the fact that subsequent elements, starting with #110, were already named without larger controversy. However, due to the fast development of the internet and social media, publishing of names proposals by institutes and single scientists

became much easier and faster. That is why in case of the nine following elements, also the information from the official websites of the institutes were taken in consideration.

Darmstadtium

The element #110 was synthesized by the group of Sigurd Hofmann from Darmstadt in 1994, and the achievement was published in 1995 (Hofmann et al. 1995a). In 2001 IUPAC claimed the priority of discovery of the German team and invited them to propose the name (Karol et al. 2001). Since I have not found the official response of the Hofmann's group for that invitation, the first official presentations of the name of the element #110 were probably three notes in *Nature* and *Pure and Applied Chemistry*, published just before and after council of IUPAC in Ottawa in August 2003. The title of the short note in Nature was: *Element 110 to be named tomorrow.* The papers in *Pure Applied Chemistry* were entitled: *On the claims for discovery of elements 110, 111, 112, 114, 116 and 118: (IUPAC Technical Report)* and *Name and symbol of the element with atomic number 110: (IUPAC Recommendations 2003)*(Ball 2003; Corish and Rosenblatt 2003; Karol et al. 2003).

Roentgenium

The first report on the discovery of element #111 was published by the team from Darmstadt in 1995. After the skeptical opinion of IUPAC, the synthesis was repeated in 2002 (Hofmann et al. 2002, 1995b). The second experiment convinced IUPAC, which claimed the right to name the element to the German team. The proposal of the name roentgenium was published by IUPAC in 2004 in *Pure and Applied Chemistry* under the title *Name and symbol of the element with atomic number 111 (IUPAC recommendations 2004)* (Corish and Rosenblatt 2004).

Copernicium

Copernicium, similarly to two previous elements, was first created in Darmstadt in 1996 (Hofmann et al. 1996). IUPAC officially recognized the discovery in 2009 (Barber et al. 2009). This decision opened the way to naming of the new element. The first information about the name appeared at the *GSI website* on July 14 2009, in the short note entitled *Element 112 shall be named "copernicium*" (GSI 2009). This information was immediately reprinted in a few popular-science journals. According to the author's studies, the first scientific magazine, publishing this information, was *Nature,* in a short note from July 22 2009, entitled *Copernicus honoured in periodic-table addition* (Nature 2009). The IUPAC's official recommendation was published in the February 2010 issue of the journal *Pure and Applied Chemistry,* entitled *Name and symbol of the element with atomic number 112 (IUPAC Recommendations 2010)*(Tatsumi and Corish 2010).

Flerovium, Livermorium

Elements #114 and #116 were synthesized by Joint Institute for Nuclear Research in Dubna (JINR), with some collaboration of the scientists from Lawrence Livermore National Laboratory in 1998 and 2000 respectively (Oganessian et al. 2001, 1999). The discovery of these elements was recognized by IUPAC in June 2011 (Barber et al.

2011). The names were proposed by Russians and presented at the *Closing Ceremony of the International Year of Chemistry* in Brussels on December 1st 2011. The first written information about the proposals of names flerovium and livermorium can be found in the note at the *JINR website* from 2nd of December 2011, entitled *Names Proposed for Elements of Atomic Number 114 and 116* (JINR 2011). This information, as in the previous case, was immediately reprinted in newspapers and popular science magazines. The official recognition of those two names took place in 2012 in the article *Names and symbols of the elements with atomic numbers 114 and 116,* published in *Pure and Applied Chemistry* (Loss and Corish 2012).

Moscovium

The element #115 was successfully synthesized in JINR in Dubna in 2003 (Oganessian et al. 2004). However, in December 2015, IUPAC/IUPAP Joint Working Party recognized only the later works of the Dubna-Livermore collaboration (from 2009), and the right to suggest a permanent name of the element, which was based on these works, was given (Karol et al. 2016a). Russians had proposed the name moscovium at least a few months earlier than the official recognition took place, traces of which can be found on Russian websites and magazines. The first official note about the name moscovium came from the website press release from Dubna, dated 6th of January 2016, entitled *Discovery of the new chemical elements with numbers 113, 115, 117 and 118* (JINR 2016). The official recognition of the name was published by IUPAC in December 2016 (Öhrström and Reedijk 2016).

Oganesson, Tennesine, Nihonium

Oganesson nuclei (Z = 118) were synthesized in Dubna in 2002, and the synthesis was repeated in 2005. The results were published in 2006, and officially recognized by IUPAC in 2016 (Karol et al. 2016b; Oganessian et al. 2006).The synthesis of the element #117, tennesine, in 2009 and 2010 was a great example of the international collaboration between several laboratories. The results were published in 2010 (Oganessian et al. 2010). IUPAC recognized the discovery in 2016 (Karol et al. 2016a).The synthesis of the element #113, nihonium, became the leading idea of Japanese scientists from Riken Institute for some time. The Japanese team managed to synthesize element #113 in 2003, and published their results in the following year (Morita et al. 2004). IUPAC finally recognized (after some troubles and criticism) the discovery in 2016 (Karol et al. 2016a).

The first official notes about the naming of elements #113, 117 and 118 has become extremely difficult and, in fact, almost impossible to establish in the times of fast flow of information on the internet, social media and in newspapers. In case of those three elements, the most reasonable official announcement may be the press release on the IUPAC webpage from june 8th 2016, entitled: *IUPAC is naming the four new elements nihonium, moscovium*, *tennessine, and oganesson* (IUPAC 2016), which was in fact the announcement of the public review of the names. On the part of a regular paper, the recognition appeared in December 2016 in the article entitled *Names and symbols of the elements with atomic numbers 113, 115, 117 and 118 (IUPAC Recommendations 2016)* published in *Pure and Applied Chemistry* (Öhrström and Reedijk 2016).

Summary

The last 120 years in terms of discovering and especially synthesizing new elements turned out to be no less turbulent than the nineteenth century. From the 1930s, physicists from American laboratories took the lead in research. World War II accelerated research into radioactive elements, mainly in terms of their military use. The nomenclature complications began in the 1940s, firstly due to the concealment of the results, and secondly, due to the lack of naming procedures for artificially synthesized elements. The Cold War between the USSR and the USA and its allies only deepened this naming inconsistency. An example was the decades-long dispute over the names of elements with atomic numbers 104 and 105, as a result of which they changed names at least four times.

The end of the Cold War also resulted in the end of the naming war and the start of wider cooperation between the centers. Work on the synthesis of the last, so far known, 9 elements was already conducted in the spirit of at most substantive competition. Thanks to that fact, by 2016, the 7th period of the Periodic Table of the Elements was completed. Work on the synthesis of further super-heavy elements is underway… (Ball 2019; Khuyagbaatar et al. 2020).

Conclusions

In the series of the three articles entitled "Name game…" the history of naming of all the known chemical elements has been presented. 118 chemical elements have been recognized as a basic building block so far, including 24 (or according to some sources only 20) non-existent in nature. Taking into consideration the assumptions, described in the introductory part of the first article of the series, the nomenclature of elements is based on more than two hundred publications, works and treatises, written in seven (or possibly eight) languages, listed in descending order: English, French, German, Swedish, Latin, Italian, Spanish and possibly Russian, as the language of the co-discoverers. These works are a great reflection of several hundred years of scientific development. The presented systematized list of naming-publications allows quick and relatively easy find of the source texts dealing with the discoveries and naming of elements and thus fills the information gap on this topic. Information scattered in many publications has been collected and merged in this series of three papers divided chronologically. As a result of the use of the source texts some inaccuracies (including dates and authors), related to the nomenclature of elements, have been clarified. However, the presented publications probably do not exhaust the subject of the nomenclature of chemical elements. Thus, the author hopes that it will be a kind of a stimulus for further discussions and research.

Acknowledgements The Author wants to express gratitude to all the following digital libraries and projects, which make their content available free of charge, therefore made it possible to contrive this publication: The Biodiversity Heritage Library, La Biblioteca Digital de la Agencia Española de Cooperación Internacional para el Desarrollo (AECID), Biblioteca Virtual de Defensa, Spain, Centre pour la Communication Scientifique Directe, France, Gallica—bibliothèque numérique de la Bibliothèque nationale de France, The Mineralogical Record magazine, Google books digital resources project, Project Gutenberg—an online library of free eBooks, The Royal Society digital library, Great Britain, Riksarkivet—National Archives of Sweden, Smithsonian Libraries and Archives,U.S., Staats- und Universitätsbibliothek Hamburg Carl

von Ossietzky, Germany, Thüringer Universitäts und Landesbibliothek Jena, Germany, Uppsala University Library, Sweden, U.S. Department of Energy Office of Scientific and Technical Information, Finally, last but not least, many thanks to Mr. Peter van der Krogt whose website was an inspiration for this article.

References

Adloff, J.-P., Kauffman, G.B.: Francium (Atomic Number 87), the Last Discovered Natural Element. Chem. Educ. (2005)

Armbruster, P., Heßberger, F.P., Hofmann, S., Leino, M., Münzenberg, G., Reisdorf, W., Schmidt, K.H.: Response to the report of the transfermium working group. Prog. Part. Nucl. Phys. (1993). https://doi.org/10.1016/0146-6410(93)90053-i

Ball, P.: Element 110 to be named tomorrow. Nature (2003). https://doi.org/10.1038/news030811-8

Ball, P.: Extreme chemistry: experiments at the edge of the periodic table. Nature **565**, 552–555 (2019). https://doi.org/10.1038/D41586-019-00285-9

Barber, R.C., Gäggeler, H.W., Karol, P.J., Nakahara, H., Vardaci, E., Vogt, E.: Discovery of the element with atomic number 112. Pure Appl. Chem. **81**, 1331–1343 (2009). https://doi.org/10.1351/PAC-REP-08-03-05

Barber, R.C., Karol, P.J., Nakahara, H., Vardaci, E., Vogt, E.W.: Discovery of the elements with atomic numbers greater than or equal to 113 (IUPAC technical report). Pure Appl. Chem. (2011). https://doi.org/10.1351/PAC-REP-10-05-01

Barber, R.C., Greenwood, N.N., Hrynkiewicz, A.Z., Jeannin, Y.P., Lefort, M., Sakai, M., Ulehla, I., Wapstra, A.H., Wilkinson, D.H.: Discovery of the transfermium elements. Part II: Introduction to discovery profiles. Part III: Discovery profiles of the transfermium elements. Pure Appl. Chem. **65**, 1757–1814 (1993). https://doi.org/10.1351/pac199365081757

Bohr, N.: Nobel lecture: The structure of the atom, (1922)

Cartlidge, E.: The battle behind the periodic table's latest additions. Nature **558**, 175–176 (2018). https://doi.org/10.1038/d41586-018-05371-y

Copernicus honoured in periodic-table addition: Nature Copernicus honoured in periodic-table addition. Nature **460**, 449–449 (2009). https://doi.org/10.1038/460449d

Corish, J., Rosenblatt, G.M.: Name and symbol of the element with atomic number 110: (IUPAC Recommendations 2003). Pure Appl. Chem. **75**, 1613–1615 (2003). https://doi.org/10.1351/pac200375101613

Corish, J., Rosenblatt, G.M.: Name and symbol of the element with atomic number 111 (IUPAC recommendations 2004). Pure Appl. Chem. (2004). https://doi.org/10.1351/pac200476122101

Corson, D.R., MacKenzie, K.R., Segrè, E.: Artificially radioactive element 85. Phys. Rev. **58**, 672–678 (1940). https://doi.org/10.1103/PhysRev.58.672

Corson, D.R., Mackenzie, K.R., Segrè, E.: Astatine: the element of atomic number. Nature **85**(59), 24 (1947)

Coster, D., Hevesy, G.: On the missing element of atomic number 72 [1]. Nature **111**, 79 (1923). https://doi.org/10.1038/111079a0

Dagani, R.: Element 106 name to honor glenn seaborg. Chem. Eng. News. **72**, 5–6 (1994). https://doi.org/10.1021/cen-v072n012.p005a

De Jonge, F.A.A., Pauwels, E.K.J.: Technetium, the missing element. Eur. J. Nucl. Med. **23**, 336–344 (1996). https://doi.org/10.1007/BF00837634

Demarçay, E.A.: Sur un nouvel élément l'europium. C. R. Hebd. Seances Acad. Sci. **132**, 1484–1486 (1901)

Elkina, V., Kurushkin, M.: Promethium: to strive, to seek, to find and not to yield. Front. Chem. **8**, 1–8 (2020). https://doi.org/10.3389/fchem.2020.00588

Erämetsä, O.: Separation of promethium from a natural lanthanide mixture. Acta Polytech. Scand. Chem. Technol. Metall. Ser. **37**, 21 (1965)

Fajans, K., Beer, P.: Das verhalten der radio-elemente bei fällungsreaktionen. Berichte Der Dtsch. Chem. Gesellschaft. **46**, 3486–3497 (1913). https://doi.org/10.1002/cber.191304603130
Fajans, K., Göhring, O.: Über das Uran X2-das neue element der uranreihe. Phys. Zeitschrift. **14**, 877–884 (1913)
Fajans, K., Morris, D.F.C.: Discovery and naming of the isotopes of element 91. Nature **244**, 137–138 (1973). https://doi.org/10.1038/244137a0
Fermi, E.: Possible production of elements of atomic number higher than 92. Nature **133**, 898–899 (1934). https://doi.org/10.1038/133898a0
Fernelius, C.: Hafnium, J. Chem. Educ. **59**(3), 242 (1982). https://doi.org/10.1021/ed059p242
Fields, P.R., Friedman, A.M., Milsted, J., Atterling, H., Forsling, W., Holm, L.W., Ãström, B.: Production of the new element 102. Phys. Rev. **107**, 1460–1462 (1957). https://doi.org/10.1103/PhysRev.107.1460
Flerov, G.N., Oganesyan, Y.T., Lobanov, Y.V., Kuznetsov, V.I., Druin, V.A., Perelygin, V.P., Gavrilov, K.A., Tret'yakova, S.P., Plotko, V.M.: Synthesis and physical identification of the isotope with mass number 260 of element 104. Sov. at. Energy **17**, 1046–1048 (1964). https://doi.org/10.1007/BF01116295
Flerov, G.N., Oganesian, Y.T., Lobanov, Y.V., Lasarev, Y.A., Tretiakova, S.P., Kolesov, I.V., Plotko, V.M.: On the synthesis of element 105. Nucl. Phys. Sect. A **160**, 181–192 (1971). https://doi.org/10.1016/0375-9474(70)90182-X
Ghiorso, A., Harvey, B.G., Choppin, G.R., Thompson, S.G., Seaborg, G.T.: New element mendelevium, atomic number 101. Phys. Rev. **98**, 1518–1519 (1955a). https://doi.org/10.1103/PhysRev.98.1518
Ghiorso, A., Thompson, S.G., Higgins, G.H., Seaborg, G.T., Studier, M.H., Fields, P.R., Fried, S.M., Diamond, H., Mech, J.F., Pyle, G.L., Huizenga, J.R., Hirsch, A., Manning, W.M., Browne, C.I., Smith, H.L., Spence, R.W.: New elements einsteinium and fermium, atomic numbers 99 and 100. Phys. Rev. **99**, 1048–1049 (1955b). https://doi.org/10.1103/PhysRev.99.1048
Ghiorso, A., Sikkeland, T., Larsh, A.E., Latimer, R.M.: New element, lawrencium, atomic number 103. Phys. Rev. Lett. **6**, 473–475 (1961). https://doi.org/10.1103/PhysRevLett.6.473
Ghiorso, A., Nurmia, M., Eskola, K., Eskola, P.: 261Rf; new isotope of element 104. Phys. Lett. B **32**, 95–98 (1970a). https://doi.org/10.1016/0370-2693(70)90595-2
Ghiorso, A., Nurmia, M., Eskola, K., Harris, J., Eskola, P.: New element hahnium, atomic number 105. Phys. Rev. Lett. **24**, 1498–1503 (1970b). https://doi.org/10.1103/PhysRevLett.24.1498
Ghiorso, A., Nitschke, J.M., Alonso, J.R., Alonso, C.T., Nurmia, M., Seaborg, G.T., Hulet, E.K., Lougheed, R.W.: Element 106. Phys. Rev. Lett. **33**, 1490–1493 (1974)
GSI: Element 112 shall be named "copernicium," https://web.archive.org/web/20090718113516/http:/www.gsi.de/portrait/Pressemeldungen/14072009_e.html
Hofmann, S., Ninov, V., Heßberger, F.P., Armbruster, P., Folger, H., Münzenberg, G., Schött, H.J., Popeko, A.G., Yeremin, A.V., Andreyev, A.N., Saro, S., Janik, R., Leino, M.: Production and decay of 269 110. Zeitschrift Für Phys. A Hadron. Nucl. **350**, 277–280 (1995a). https://doi.org/10.1007/BF01291181
Hofmann, S., Ninov, V., Heßberger, F.P., Armbruster, P., Folger, H., Münzenberg, G., Schött, H.J., Popeko, A.G., Yeremin, A.V., Andreyev, A.N., Saro, S., Janik, R., Leino, M.: The new element 111. Zeitschrift Für Phys. A Hadron. Nucl. **350**, 281–282 (1995b). https://doi.org/10.1007/BF01291182
Hofmann, S., Ninov, V., Heßberger, F.P., Armbruster, P., Folger, H., Münzenberg, G., Schött, H.J., Popeko, A.G., Yeremin, A.V., Saro, S., Janik, R., Leino, M.: The new element 112. Zeitschrift Für Phys. A Hadron. Nucl. **354**, 229–230 (1996). https://doi.org/10.1007/bf02769517
Hofmann, S., Heßberger, F.P., Ackermann, D., Münzenberg, G., Antalic, S., Cagarda, P., Kindler, B., Kojouharova, J., Leino, M., Lommel, B., Mann, R., Popeko, A.G., Reshitko, S., Śaro, S., Uusitalo, J., Yeremin, A.V.: New results on elements 111 and 112. Eur. Phys. J. A Hadron. Nucl. **14**, 147–157 (2002). https://doi.org/10.1140/epja/i2001-10119-x
Hulubei, H., Cauchois, Y.: Spectres de l'émission propre ondulatorie du radon et de ses dérivés. Raies attribuables à l'élément 85. Comptes Rendus De Seances L'academie Des Sci. **209**, 39–42 (1939)
IUPAC: Names and symbols of transfermium elements (IUPAC Recommendations 1994). Pure Appl. Chem. **66**, 2419–2421 (1994). https://doi.org/10.1351/pac199466122419
IUPAC: Names and symbols of transfermium elements (IUPAC Recommendations 1997). Pure Appl. Chem. **69**, 2471–2474 (1997). https://doi.org/10.1351/pac199769122471
IUPAC: IUPAC is naming the four new elements nihonium, moscovium, tennessine, and oganesson, https://iupac.org/iupac-is-naming-the-four-new-elements-nihonium-moscovium-tennessine-and-oganesson/
JINR: Discovery of the new chemical elements with numbers 113, 115, 117 and 118, http://www.jinr.ru/posts/discovery-of-the-new-chemical-elements-with-numbers-113-115-117-and-118-2/
JINR: Names Proposed for Elements of Atomic Number 114 and 116, http://www.jinr.ru/posts/post_3155/
Karlik, B., Bernert, T.: Eine neue natürliche α-Strahlung. Naturwissenschaften **31**, 298–299 (1943). https://doi.org/10.1007/BF01475613

Karol, P.J., Nakahara, H., Petley, B.W., Vogt, E.: On the discovery of the elements 110–112 (IUPAC Technical Report). Pure Appl. Chem. **73**, 959–967 (2001). https://doi.org/10.1351/pac200173060959

Karol, P.J., Nakahara, H., Petley, B.W., Vogt, E.: On the claims for discovery of elements 110, 111, 112, 114, 116, and 118: (IUPAC Technical Report). Pure Appl. Chem. **75**, 1601–1611 (2003). https://doi.org/10.1351/pac200375101601

Karol, P.J., Barber, R.C., Sherrill, B.M., Vardaci, E., Yamazaki, T.: Discovery of the elements with atomic numbers Z = 113, 115 and 117 (IUPAC Technical Report). Pure Appl. Chem. **88**, 139–153 (2016a). https://doi.org/10.1515/pac-2015-0502

Karol, P.J., Barber, R.C., Sherrill, B.M., Vardaci, E., Yamazaki, T.: Discovery of the element with atomic number Z = 118 completing the 7th row of the periodic table (IUPAC Technical Report). Pure Appl. Chem. **88**, 155–160 (2016b). https://doi.org/10.1515/pac-2015-0501

Kenna, B.T., Kuroda, P.K.: Isolation of naturally occurring technetium. J. Inorg. Nucl. Chem. **23**, 142–144 (1961). https://doi.org/10.1016/0022-1902(61)80098-5

Kennedy, J.W., Perlman, M.L., Segre, E., Wahl, A.C.: Formation of the 50-Year Element 94 from Deuteron Bombardment of U 238. , Argonne, IL (United States) (1942)

Khuyagbaatar, J., Yakushev, A., Düllmann, C.E., Ackermann, D., Andersson, L.L., Asai, M., Block, M., Boll, R.A., Brand, H., Cox, D.M., Dasgupta, M., Derkx, X., Di Nitto, A., Eberhardt, K., Even, J., Evers, M., Fahlander, C., Forsberg, U., Gates, J.M., Gharibyan, N., Golubev, P., Gregorich, K.E., Hamilton, J.H., Hartmann, W., Herzberg, R.D., Heßberger, F.P., Hinde, D.J., Hoffmann, J., Hollinger, R., Hübner, A., Jäger, E., Kindler, B., Kratz, J.V., Krier, J., Kurz, N., Laatiaoui, M., Lahiri, S., Lang, R., Lommel, B., Maiti, M., Miernik, K., Minami, S., Mistry, A.K., Mokry, C., Nitsche, H., Omtvedt, J.P., Pang, G.K., Papadakis, P., Renisch, D., Roberto, J.B., Rudolph, D., Runke, J., Rykaczewski, K.P., Sarmiento, L.G., Schädel, M., Schausten, B., Semchenkov, A., Shaughnessy, D.A., Steinegger, P., Steiner, J., Tereshatov, E.E., Thörle-Pospiech, P., Tinschert, K., Torres De Heidenreich, T., Trautmann, N., Türler, A., Uusitalo, J., Wegrzecki, M., Wiehl, N., Van Cleve, S.M., Yakusheva, V.: Search for elements 119 and 120. Phys. Rev. C. (2020). https://doi.org/10.1103/PHYSREVC.102.064602

Koppenol, W.H.: Paneth, IUPAC, and the naming of elements. Helv. Chim. Acta. **88**, 95–99 (2005). https://doi.org/10.1002/hlca.200490300

Kragh, H.: The Transfermium Wars. In: From Transuranic to Superheavy Elements A Story of Dispute and Creation, pp. 59–75. Springer (2018)

Letter, T.S.N.: Element 101 discovered. Sci. News-Letter. **67**, 307 (1955)

Letter, T.S.N.: Make new element 102. Sci. News-Letter. **72**, 35 (1957)

Lipkin, R.: Element 106 takes the name seaborgium. Sci. News **145**, 180 (1994). https://doi.org/10.2307/3978136

Loss, R.D., Corish, J.: Names and symbols of the elements with atomic numbers 114 and 116 (IUPAC recommendations 2012). Pure Appl. Chem. (2012). https://doi.org/10.1351/PAC-REC-11-12-03

Marinsky, J.A., Glendenin, L.E.: A proposal of the name prometheum for element 61. Chem. Eng. News. **26**, 2346–2348 (1948). https://doi.org/10.1021/cen-v026n032.p2346

Marinsky, J.A., Glendenin, L.E., Coryell, C.D.: The chemical identification of radioisotopes of neodymium and of element 61. J. Am. Chem. Soc. (1947). https://doi.org/10.1021/ja01203a059

McMillan, E., Abelson, P.H.: Radioactive element 93. Phys. Rev. **57**, 1185–1186 (1940). https://doi.org/10.1103/PhysRev.57.1185.2

Meitner, L.: Die muttersubstanz des actiniums, ein neues radioaktives element von langer lebensdauer. zeitschrift für elektrochemie und angew. Phys. Chemie. **24**, 169–173 (1918)

Meitner, L., Hahn, O.: Die muttersubstanz des actiniums, ein neues radioactives element von langer lebensdauer. Phys. Zeitschrift. **19**, 208–218 (1918)

Morita, K., Morimoto, K., Kaji, D., Akiyama, T., Goto, S.I., Haba, H., Ideguchi, E., Kanungo, R., Katori, K., Koura, H., Kudo, H., Ohnishi, T., Ozawa, A., Suda, T., Sueki, K., Xu, H.S., Yamaguchi, T., Yoneda, A., Yoshida, A., Zhao, Y.L.: Experiment on the synthesis of element 113 in the reaction 209Bi (70Zn, n)278113. J. Phys. Soc. Japan. **73**, 2593–2596 (2004). https://doi.org/10.1143/JPSJ.73.2593

Münzenberg, G., Hofmann, S., Heßberger, F.P., Reisdorf, W., Schmidt, K.H., Schneider, J.H.R., Armbruster, P., Sahm, C.C., Thuma, B.: Identification of element 107 by α correlation chains. Zeitschrift Für Phys. A Atoms Nucl. **300**, 107–108 (1981). https://doi.org/10.1007/BF01412623

Münzenberg, G., Armbruster, P., Heßberger, F.P., Hofmann, S., Poppensieker, K., Reisdorf, W., Schneider, J.H.R., Schneider, W.F.W., Schmidt, K.-H., Sahm, C.-C., Vermeulen, D.: Observation of one correlated α -decay in the reaction 58 Fe on 209 Bi→ 267 109. Zeitschrift Für Phys. A Atoms Nucl. **309**, 89–90 (1982). https://doi.org/10.1007/BF01420157

Münzenberg, G., Armbruster, P., Folger, H., Heßberger, P.F., Hofmann, S., Keller, J., Poppensieker, K., Reisdorf, W., Schmidt, K.H., Schött, H.J., Leino, M.E., Hingmann, R.: The identification of element 108. Zeitschrift Für Phys. A Atoms Nucl. **317**, 235–236 (1984). https://doi.org/10.1007/BF01421260

Noddack, W., Tacke, I., Berg, O.: Die ekamangane. Naturwissenschaften **13**, 567–574 (1925). https://doi.org/10.1007/BF01558746

Oganessian, Y.T., Demin, A.G., Danilov, N.A., Flerov, G.N., Ivanov, M.P., Iljinov, A.S., Kolesnikov, N.N., Markov, B.N., Plotko, V.M., Tretyakova, S.P.: On spontaneous fission of neutron-deficient isotopes of elements 103, 105 and 107. Nucl. Phys. A **273**, 505–522 (1976). https://doi.org/10.1016/0375-9474(76)90607-2

Oganessian, Y.T., Utyonkov, V.K., Lobanov, Y.V., Abdullin, F.S., Polyakov, A.N., Shirokovsky, I.V., Tsyganov, Y.S., Gulbekian, G.G., Bogomolov, S.L., Gikal, B.N., Mezentsev, A.N., Iliev, S., Subbotin, V.G., Sukhov, A.M., Buklanov, G.V., Subotic, K., Itkis, M.G., Moody, K.J., Wild, J.F., Stoyer, N.J., Stoyer, M.A., Lougheed, R.W.: Synthesis of superheavy nuclei in the 48Ca + 244Pu reaction. Phys. Rev. Lett. **83**, 3154–3157 (1999). https://doi.org/10.1103/PhysRevLett.83.3154

Oganessian, Y.T., Utyonkov, V.K., Lobanov, Y.V., Abdullin, F.S., Polyakov, A.N., Shirokovsky, I.V., Tsyganov, Y.S., Gulbekian, G.G., Bogomolov, S.L., Gikal, B.N., Mezentsev, A.N., Iliev, S., Subbotin, V.G., Sukhov, A.M., Ivanov, O.V., Buklanov, G.V., Subotic, K., Itkis, M.G., Moody, K.J., Wild, J.F., Stoyer, N.J., Stoyer, M.A., Lougheed, R.W., Laue, C.A., Karelin, Y.A., Tatarinov, A.N.: Observation of the decay of 292116. Phys. Rev. C Nucl. Phys. **63**, 113011–113012 (2001). https://doi.org/10.1103/PhysRevC.63.011301

Oganessian, Y.T., Utyonkoy, V.K., Lobanov, Y.V., Abdullin, F.S., Polyakov, A.N., Shirokovsky, I.V., Tsyganov, Y.S., Gulbekian, G.G., Bogomolov, S.L., Mezentsev, A.N., Iliev, S., Subbotin, V.G., Sukhov, A.M., Voinov, A.A., Buklanov, G.V., Subotic, K., Zagrebaev, V.I., Itkis, M.G., Patin, J.B., Moody, K.J., Wild, J.F., Stoyer, M.A., Stoyer, N.J., Shaughnessy, D.A., Kenneally, J.M., Lougheed, R.W.: Experiments on the synthesis of element 115 in the reaction [Formula Presented]. Phys. Rev. C Nucl. Phys. **69**, 5 (2004). https://doi.org/10.1103/PhysRevC.69.021601

Oganessian, Y.T., Utyonkov, V.K., Lobanov, Y.V., Abdullin, F.S., Polyakov, A.N., Sagaidak, R.N., Shirokovsky, I.V., Tsyganov, Y.S., Voinov, A.A., Gulbekian, G.G., Bogomolov, S.L., Gikal, B.N., Mezentsev, A.N., Iliev, S., Subbotin, V.G., Sukhov, A.M., Subotic, K., Zagrebaev, V.I., Vostokin, G.K., Itkis, M.G., Moody, K.J., Patin, J.B., Shaughnessy, D.A., Stoyer, M.A., Stoyer, N.J., Wilk, P.A., Kenneally, J.M., Landrum, J.H., Wild, J.F., Lougheed, R.W.: Synthesis of the isotopes of elements 118 and 116 in the Cf249 and Cm245+Ca48 fusion reactions. Phys. Rev. C Nucl. Phys. **74**, 44602 (2006). https://doi.org/10.1103/PhysRevC.74.044602

Oganessian, Y.T., Abdullin, F.S., Bailey, P.D., Benker, D.E., Bennett, M.E., Dmitriev, S.N., Ezold, J.G., Hamilton, J.H., Henderson, R.A., Itkis, M.G., Lobanov, Y.V., Mezentsev, A.N., Moody, K.J., Nelson, S.L., Polyakov, A.N., Porter, C.E., Ramayya, A.V., Riley, F.D., Roberto, J.B., Ryabinin, M.A., Rykaczewski, K.P., Sagaidak, R.N., Shaughnessy, D.A., Shirokovsky, I.V., Stoyer, M.A., Subbotin, V.G., Sudowe, R., Sukhov, A.M., Tsyganov, Y.S., Utyonkov, V.K., Voinov, A.A., Vostokin, G.K., Wilk, P.A.: Synthesis of a new element with atomic number Z=117. Phys. Rev. Lett. **104**, 142502 (2010). https://doi.org/10.1103/PhysRevLett.104.142502

Ogawa, M.: Preliminary note on a new element in thorianit. J. Coll. Sci. Imp. Univ. Tokyo. **25**, 1–11 (1908)

Öhrström, L., Reedijk, J.: Names and symbols of the elements with atomic numbers 113, 115, 117 and 118 (IUPAC Recommendations 2016). Pure Appl. Chem. (2016). https://doi.org/10.1515/pac-2016-0501

Оганесян, ЮЦ, Третьяков, ЮП, Ильинов, А.С., Демин, А.Г, Плеве, А.А., Третьякова, С.П, Плотко, В.М., Иванов, М.П, Данилов, Н.А., Короткин, Ю.С., Флеров, Г.Н.: Синтез нейтронодефицитных изотопов фермия, курчатовия и элемента с атомным номером 106. Письма в Жэтф. **20**, 580–585 (1974)

Paneth, F.A.: The making of the missing chemical elements. Nature **159**, 8–10 (1947). https://doi.org/10.1038/159008a0

Peppard, D.F., Mason, G.W., Gray, P.R., Mech, J.F.: Occurrence of the (4n + 1) Series in Nature. J. Am. Chem. Soc. **74**, 6081–6084 (1952). https://doi.org/10.1021/ja01143a074

Perey, M.: L'élément 87: AcK, dérivé de l'actinium. J. Phys. Le Radium (1939a). https://doi.org/10.1051/jphysrad:01939a0010010043500

Perey, M.: Sur un élément 87, dérivé de l'actinium. Comptes Rendus Hebd Des Séances L'académie Des Sci. **208**, 97–99 (1939b)

Perey, M.: L'élément 87. J. Chim. Phys. **43**, 155–168 (1946b)

Perey, M.: Propriétés chimiques de l'élément 87: actinium K. J. Chim. Phys. **43**, 262–268 (1946c)

Perey, M.: Propriétés physiques de l'élément 87: actinium K et son emploi dans le dosage de l'actinium. J. Chim. Phys. **43**, 269–278 (1946d)

Perey, M.: Elément 87, actinium K, doctoral thesis (1946a)

Perrier, C., Segré, E.: Alcune proprieta chimiche dell'elemento 43. Rend. Della R Acad. Naz. Dei Lincei. **25**, 723–730 (1937)
Perrier, C., Segrè, E.: Radioactive isotopes of element 43. Nature **140**, 193–194 (1937). https://doi.org/10.1038/140193b0
Perrier, C., Segrè, E.: Technetium: the element of atomic number 43. Nature **159**, 24 (1947)
Preston, S.S.: Marguerite Perey (1909–1975): Discoverer of Francium. In: The Posthumous Nobel Prize in Chemistry. Ladies in Waiting for the Nobel Prize. American Chemical Society. Vol. 2, pp. 245–263 (2018). https://doi.org/10.1021/bk-2018-1311.ch010
Rayner-Canham, G., Zheng, Z.: Naming elements after scientists: An account of a controversy. Found. Chem. **10**, 13–18 (2008). https://doi.org/10.1007/s10698-007-9042-1
Robinson, A.E.: Attempting neutrality: Disciplinary and national politics in a Cold War scientific controversy. Centaurus **63**, 84–102 (2021). https://doi.org/10.1111/1600-0498.12328
Scerri, E.: A Tale of Seven Elements. Oxford University Press (2013)
Science: Science: U. S. news and notes. Science **103**, 480–482 (1946). https://doi.org/10.1126/science.103.2677.480
Science: Element 103 Created and Identified by Berkeley Research Group. Science (80). **133**, 1225 (1961). https://doi.org/10.1126/science.133.3460.12
Seaborg, G.T.: The chemical and radioactive properties of the heavy elements. Chem. Eng. News. (1945). https://doi.org/10.1021/cen-v023n023.p2190
Seaborg, G.T.: The impact of nuclear chemistry. Chem. Eng. News. **24**, 1192–1198 (1946). https://doi.org/10.1021/cen-v024n009.p1192
Seaborg, G.T., Hamilton, J.G.: The production of elements 95 and 96. Science **102**, 556 (1945). https://doi.org/10.1126/science.102.2657.556-a
Seaborg, G.T., Perlman, M.L.: Search for Elements 94 and 93 in Nature. Presence of 94239 in Pitchblende1. J. Am. Chem. Soc. **70**, 1571–1573 (1948). https://doi.org/10.1021/ja01184a083
Sime, R.L.: The search for transuranium elements and the discovery of nuclear fission. Phys. Perspect. **2**, 48–62 (2000). https://doi.org/10.1007/s000160050036
Sime, R.L.: The discovery of protactinium, J. Chem. Educ. **63**(8), 653 (1986). https://doi.org/10.1021/ed063p653
Soddy, F., Cranston, J.: The parent of actinium. Proc. R. Soc. London. Ser. A Contain Pap. A Math. Phys. Character **94**, 384–404 (1918). https://doi.org/10.1098/rspa.1918.0025
Still, B.: The unveiled states of americium. Nature Chem **9**, 296 (2017). https://doi.org/10.1038/nchem.2733
Tatsumi, K., Corish, J.: Name and symbol of the element with atomic number 112 (IUPAC recommendations 2010). Pure Appl. Chem. **82**(3), 753–755 (2010). https://doi.org/10.1351/PAC-REC-09-08-20
The Science News Letter: Rapid Assembling. Sci. News Lett. **48**, 102 (1945a)
The Science News Letter: Idea for Plutonium Bomb Credited to Dr Lawrence. Sci. News-Letter. **48**, 102 (1945b)
The Science News Letter: Made to order. Sci. News Lett. **48**, 103 (1945c)
The Science News Letter: No 97 dubbed berkelium. Sci. News-Letter. **57**, 51 (1950a). https://doi.org/10.2307/3927712
The Science News Letter: Californium element 98. Sci. News Lett. **57**, 182 (1950b)
Thompson, S.G., Street, K., Ghiorso, A., Seaborg, G.T.: Element 98. Phys. Rev. **78**, 298–299 (1950b). https://doi.org/10.1103/PhysRev.78.298.2
Thompson, S.G., Ghiorso, A., Seaborg, G.T.: Element 97. Phys. Rev. **77**, 838 (1950). https://doi.org/10.1103/PhysRev.77.838.2
Thornton, B.: Finding eka-iodine: discovery priority in modern times. Bull. Hist. Chem. **35**, 86–96 (2010)
Urbain, G.: Un nouvel élément : le lutécium, résultant du dédoublement de l'ylterhium de Marignac. C. r. Hebd. Seances Acad. Sci. **145**, 759–762 (1907)
Yoshihara, H.K.: Discovery of a new element "nipponium": Re-evaluation of pioneering works of Masataka-Ogawa and his son Eijiro Ogawa. Spectrochim Acta B At Spectrosc **59**(8), 1305–1310 (2004). https://doi.org/10.1016/j.sab.2003.12.027. https://doi.org/10.1016/j.sab.2003.12.027