IUPAC Recommendations

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Names and symbols of the elements with atomic numbers 113, 115, 117 and 118 (IUPAC Recommendations 2016)

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Abstract: A joint IUPAC/IUPAP Working Party (JWP) has confirmed the discovery of the elements with atomic numbers (*Z*) 113, 115, 117 and 118. In accordance with the 2016 IUPAC guideline for naming new elements, the discoverers were invited to propose names and symbols for the elements. Claims have been assigned to them and the following are proposed: (a) nihonium and symbol Nh, for the element with $Z=113$, (b) moscovium with the symbol Mc, for the element with $Z=115$, (c) tennessine with the symbol Ts, for the element with $Z=117$, and oganesson with the symbol Og, for the element with $Z=118$. After careful deliberation on these names and symbols, considering the 2016 rules and a public review period, the Inorganic Chemistry Division recommended these proposals for acceptance by the IUPAC Council.

Keywords: element 113; element 115; element 117; element 118; element name; IUPAC Inorganic Chemistry Division; moscovium; new elements; nihonium; oganesson; periodic table; recommendations; superheavy elements; tennessine.

CONTENTS

1 Introduction

In 2005, a Joint Working Party (JWP, formerly also called JWG) of independent experts drawn from IUPAC and the International Union of Pure and Applied Physics (IUPAP) was appointed by the presidents of these organizations to determine priority of claims to the discovery of new chemical elements. The JWP worked

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according to the criteria for the discovery of elements previously established by the 1991–1993 IUPAC/IUPAP Transfermium Working Group [1–3]. A summary of the current criteria and procedure was recently published in *Chemistry International* [4].

The JWP has earlier reported [5–7] on the discovery of elements with atomic numbers 112, 114, and 116. These elements were subsequently named copernicium, with symbol Cn [8]; livermorium, with symbol Lv; and flerovium, with symbol Fl; respectively [9].

The JWP reports on the claims of priority of discovery of elements with atomic numbers 113, 115, 117, and 118 were submitted in 2015; prior to publication, each of the claimant laboratories was asked to check the contents and findings in these drafts for technical accuracy. The reports were also reviewed by independent expert referees. Finally, the findings were accepted by the Division Committee of the IUPAC Division of Inorganic Chemistry (Division II) and by the Executive Committees of the two Unions. The reports were subsequently published in *Pure and Applied Chemistry* [10, 11]. Priorities for the claims of discovery were determined as follows.

The RIKEN collaboration, of Morita *et al*. [12–15] has fulfilled the criteria [1–3] for element $Z = 113$ [10].

The collaborating laboratories in Dubna, Livermore, and Oak Ridge coordinated by Oganessian, *et al*. [16–20] have fulfilled the criteria [1–3] for elements with $Z = 115$ and 117 [10].

The results of the collaboration between the laboratories in Dubna and Livermore [21] have satisfied the criteria for discovery of element 118 [11].

2 Recommendations of names and symbols for the four new elements

The role of IUPAC is to provide a technical review of the names and symbols proposed by the discoverers. In early 2016, the recommendations for naming elements of 2002 [22] was revised to allow newly discovered elements belonging to the halogen and noble gas Groups to have appropriate endings [23]. Its main points are summarized here. In keeping with tradition, newly discovered elements can be named after:

- a mythological concept or character (including an astronomical object),
- a mineral, or similar substance,
- a place, or geographical region,
- a property of the element, or
- a scientist.

To avoid confusion in the literature, when a name has been used for a particular element, but a different name has ultimately been chosen for that element then the first name cannot be transferred for use for another element. The names of all new elements should have an ending that reflects and maintains historical and chemical consistency. This would be, in general, "-ium" for elements belonging to Groups 1–16, including lanthanoids and actinoids, "-ine" for elements of Group 17, and "-on" for elements of Group 18. Finally, we note from the IUPAC 2005 recommendations [24] that: "It is obviously desirable that the names used in any language resemble these names as closely as possible, but it is recognized that for elements named in the past there are often well-established and very different names in other languages".

Following the acceptance of the claims, and in accordance with the procedures established by IUPAC for the naming of elements [23], whereby the discoverers are accorded the right to propose a name and a symbol, the discoverers at RIKEN Nishina Centre for Accelerator-Based Science (Japan), Joint Institute for Nuclear Research, Dubna (Russia), Oak Ridge National Laboratory (USA), and Lawrence Livermore National Laboratory (USA) were invited by IUPAC to propose names and symbols for the elements with atomic numbers 113 (RIKEN), 115 and 117 (Dubna, Livermore, Oak Ridge), and 118 (Dubna and Livermore). The outcomes of this process are as follows:

2.1 Element 113

The name **nihonium** and symbol **Nh** are proposed for the element with $Z = 113$. Nihon is one of the two ways to say "Japan" in Japanese. The name is proposed to make a direct connection to the nation where it was discovered and also to celebrate the fact that it is the very first element in the history of the Periodic Table to be discovered in, and to be named after, an Asian country.

The discoverers respectfully note the 1909 claim, and never sustained proposal, by Masataka Ogawa for nipponium as element with $Z = 43$ [25, 26]. The name nihonium is also in homage to his work.

2.2 Element 115

It is proposed that the name **moscovium** and symbol **Mc** are given to element 115. Moscovium is recommended in recognition of the Moscow region and to honour the ancient Russian land that is home to the Joint Institute for Nuclear Research, where the discovery experiments were conducted with the Dubna Gas-Filled Recoil Separator in combination with the heavy-ion accelerator capabilities of the Flerov Laboratory of Nuclear Reactions, JINR.

2.3 Element 117

The name **tennessine** and symbol **Ts** are proposed for element 117. Tennessine is recommended in recognition of the contribution of the Tennessee region (state, USA), including Oak Ridge National Laboratory, Vanderbilt University, and the University of Tennessee at Knoxville, to superheavy element research, including the production and chemical separation of unique actinoid target materials for superheavy element synthesis. Actinoid materials from Oak Ridge have contributed to the discovery and/or confirmation of nine superheavy elements. As element 117 belongs to Group 17, the ending of the name is "-ine".

Note 1: During the review process, it was recognized that Ts is also one of the two abbreviations used for the tosyl group. However, this was not considered sufficiently important to avoid choosing Ts. Other symbols such as Ac (element 89) or Pr (element 59) are also used by chemists as abbreviations for the acetyl and the propyl groups, respectively. Any chemist would be able to discriminate between the different meanings from their contexts, and therefore there was no need to sacrifice the name proposed by the discoverers. It was realized also that the symbol Tn, that might have been an alternative suggestion, is no longer possible given the earlier (1923) CIAAW-IUPAC acceptance of that symbol for thoron (^{220}Rn) and its regular usage since then (see e.g. Journal of Environmental Radioactivity).

Note 2: The roots of the names of the preceding halogens are fluere (Latin) and chloros, bromos, iodes, and astatos (Greek) [27], which in English have become fluorine, chlorine, bromine, iodine, and astatine. However, in many other languages the halogens have been given shorter names, such as cloro in Spanish and Italian, Chlor in German and chlore in French. Thus, the regular endings of the halogens in English are not a rule in all languages. The name Tennessee derives from the Cherokee language and the name of the village Tanasi, as explained in [28]. The name can be translated, converted or adapted to the use in, and needs of, any language, such as the halogen consistency in a given language. It is hoped that this brief etymological excursion is of some help in deriving the name in other languages.

2.4 Element 118

The collaborating teams have proposed the name **oganesson** and the symbol **Og** for element 118. Oganesson is proposed in recognition of Prof. Yuri T. Oganessian (born 1933) for his pioneering contributions to transactinoid elements research over an extensive period of time. His many achievements include the discovery

of superheavy elements and significant advances in the nuclear physics of superheavy nuclei, including experimental evidence for the "island of stability". As element 118 belongs to Group 18, the ending of the name is "-on".

Note 3: This is the second element named after a living person, the first being element 106, named seaborgium in 1997 in honor of transuranium element pioneer Glenn T. Seaborg (1912–1999) [29].

3 Summary

The Inorganic Chemistry Division Committee considered the proposals of the discoverers' laboratories, and it recommended to the IUPAC Bureau and Council that the names nihonium, with the symbol Nh; moscovium, with the symbol Mc; tennessine, with the symbol Ts; and oganesson, with the symbol Og; be accepted for the elements with atomic numbers 113, 115, 117, and 118, respectively. These provisional recommendations of the names and symbols were made available for review and comment in May 2016. The final recommendations were approved by the IUPAC Bureau in November 2016, as authorized by the Council at its meeting in 2015. This final part of the process followed the statutory period during which the recommendations were open for public comment for a period of 5 months.

Finally, as serious claims associated with elements having $Z = 119$ or above have not yet been made, we note that, for the first time, the Periodic Table exists with all elements named and no proposed or pending new additions. This, however, does not mean that the Periodic Table is complete, and a new JWP is being planned already by IUPAC and IUPAP.

Membership of sponsoring bodies

Membership of the Inorganic Chemistry Division Committee for the period 2016–2017 is as follows: President: J. Reedijk (The Netherlands); Vice President: L. Öhrström (Sweden), Secretary: M. Leskela (Finland); Titular Members: L. Armelao (Italy), T. Ding (China), P. Karen (Norway), R. D. Loss (Australia) D. Rabinovich (USA), T. Walczyk (Singapore/Switzerland), M. Wieser (Canada); Associate Members: Y. Abdul Aziz (Malaysia), J. Colón (Puerto Rico), M. Drabik (Slovakia), L. Meesuk (Thailand), K. Sakai (Japan), N. Trendafilova (Bulgaria); National Representatives: J. Darkwa (South Africa), M. Diop (Senegal), L. Galamba-Correia (Portugal), M. Hasegawa (Japan), S. Kalmykov (Russia), A. Kiliç (Turkey), P. Knauth (France), G.J. Leigh (UK), S. Mathur (Germany), K.B. Yoon (South Korea).

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