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Names and Symbols of the Elements with Atomic Numbers 113, 115, 117 and 118

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INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

INORGANIC CHEMISTRY DIVISION

Names and Symbols of the Elements with Atomic Numbers 113, 115, 117 and 118

Provisional Recommendations &

Lars Öhrström [a] and Jan Reedijk [b,*]

a) Department of Chemistry and Chemical Engineering, Chalmers University of Technology, SE-412 96, Gothenburg, Sweden,

b) Leiden Institute of Chemistry, Leiden University, P.O. Box 9502, 2300 RA, Leiden, The Netherlands

*Corresponding author at: Reedijk@chem.leidenunivnl

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Provisional Recommendations

Abstract: A joint IUPAC/IUPAP Working Party (JWP) has confirmed the discovery of the elements with atomic numbers 113, 115, 117 and 118. In accord with IUPAC procedures, the discoverers proposed names as follows:

* Nihonium and symbol Nh, for the element with *Z* =113,
* Moscovium with the symbol Mc, for the element with *Z* = 115,
* 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 checking the Inorganic Chemistry Division recommends these proposals for acceptance and they were adopted by IUPAC by the Bureau on (*date to be inserted, after the 5 months public review*) as delegated to act by the IUPAC Council meeting on 12-13 August 2015.

KEYWORDS: periodic table; new elements; element 113, element 115, element 117, element 118; element name; recommendations; nihonium; moscovium; tennessine; oganesson; IUPAC; superheavy elements

1. INTRODUCTION

In 2005 a Joint Working Party (JWP) of independent experts drawn from IUPAC and IUPAP was appointed by the presidents of the IUPAC and IUPAP to determine priority of claims to the discovery of new chemical elements. After its most recent 2011 reports on elements with atomic numbers higher than 112 [1, 2], the JWP was asked to continue their work in 2012.

The JWP first considered literature and documentation submitted to it by 31 May 2012. All of its deliberations were carried out in accordance with the criteria for the discovery of elements previously established by the 1992 IUPAC/IUPAP Transfermium Working Group [3-5] and reinforced in subsequent IUPAC/IUPAP JWP discussions. The most recent summary of the current regulations is available from Chemistry International [6].

The JWP has previous reported [1, 2, 7] on the discovery of elements with atomic numbers 112, 114 and 116 and these elements were subsequently named copernicium with the symbol Cn [8], livermorium with symbol Lv and flerovium with symbol Fl, respectively [9].

The JWP reports on the priorities and the claims of elements with atomic numbers 113, 115, 117 and 118 were submitted in 2015, and prior to publication each of the claimant laboratories were asked to check the contents and findings in these drafts for technical accuracy. The reports were also reviewed by fifteen independent expert referees, and finally the findings were accepted by the Executive Committees of the two Unions, and by the Division Committee of the IUPAC Division of Inorganic Chemistry (Division II). Subsequently, the reports were published in two papers (back to back in an issue of PAC, [10, 11]) and the priorities for the claims were determined as follows:

In full accordance with the criteria for the discovery of elements previously established by the 1991 IUPAC/IUPAP Transfermium Working Group (TWG), and reinforced in subsequent IUPAC/IUPAP JWP discussions, it was determined that the RIKEN collaboration or Morita *et al*. [12-15] has fulfilled those criteria for element Z =113 [10]. Three chains of ^{278}113 observed by the RIKEN collaborations, the first in 2004 [10], the second in 2007 [10] and the third in 2012 [10], were accepted as being consistent [10].

The claims for 115 and 117 by the Dubna–Livermore–Oak Ridge collaborations of Oganessian *et al.* [16-20] are credited likewise [10]. The 2010 collaborations of Oganessian *et al.* [16, 17] jointly with the 2013 work [20] have met the criteria for discovery of the element with atomic number Z =115 in as much as the reproducibility of alpha chain energies and lifetimes of ^{289}115 in a cross reaction comparison is very convincing. Likewise the ^{48}Ca + ^{249}Bk fusion reaction [16,17] to produce the compound nucleus ^{297}117 leading to three complete four-member chains commencing with ^{293}117 and subsequently reproduced [19], has been accepted as convincing [10].

The 2006 Dubna–Livermore collaboration of Oganessian *et al.* [21] produced three concordant decay chains commencing with ^{294}118. This result was confirmed in 2012. Three other independent heavy-element fusion studies served to identify and confirm the existence and decay properties of ^{294}118 descendants ^{290}Lv and ^{286}Fl serving to link atomic numbers through cross bombardments. Therefore the Dubna–Livermore 2006 collaboration has satisfied the criteria for discovery and its claim [21] is now acknowledged as validated [11].

2. RECOMMENDATION OF NAMES AND SYMBOLS FOR THE FOUR NEW ELEMENTS

The most recent paper covering the element naming guidelines is available since early 2016 [22], and its main points are summarized here. In keeping with tradition, newly discovered elements can be named after:

(a) a mythological concept or character (including an astronomical object),

(b) a mineral, or similar substance,

(c) a place, or geographical region,

(d) a property of the element, or

(e) a scientist.

To avoid confusion in the literature, when a name has been used for a particular element, but a different name is ultimately chosen for that element, then the first name cannot be transferred for use for another element. The names of all new elements in general would have an ending that reflects and maintains historical and chemical consistency. This would be in general “-ium” for elements belonging to groups 1-16, “-ine” for elements of group 17 and “-on” for elements of group 18. Finally the names for new chemical elements in English, should allow proper translation into other major languages.

Following the assignment and in accordance with the procedures established by IUPAC for the naming of elements [22], the discoverers at RIKEN Nishina Center 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, 117 (Dubna, Livermore, Oak Ridge) and 118 (Dubna and Livermore). The outcomes of this process are as follows:

Element 113

The name **nihonium** and symbol **Nh** are proposed for element 113. Nihon is one of the two ways to say “Japan” in Japanese, and 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.

NB: The discoverers respectfully note the 1909, never sustained, claim and proposal by Masataka Ogawa for nipponium as element 43 [23, 24] and the name is also a homage to his work.

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 honoring the ancient Russian land that is home to the Joint Institute for Nuclear Research, where the discovery experiments were conducted using the Dubna Gas-Filled Recoil Separator in combination with the heavy-ion accelerator capabilities of the Flerov Laboratory of Nuclear Reactions, JINR.

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, 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 actinide target materials for superheavy element synthesis. Actinoid materials from Oak Ridge have contributed to the discovery and/or confirmation of nine superheavy elements.

NB: We are aware of the fact that Ts is often used as abbreviation for the tosyl chemical group. However, this was not considered to be a valid objection, given the fact that we also use the symbols Ac and Pr for chemical elements, while chemists also use these as abbreviations for the acyl and the propyl groups. Very common items like AcOH and PrOH are usually not taken for the hydroxides of actinium and praseodymium and a possible confusion with the tosyl group seem extremely low. On the other hand, the abbreviation Tn, that might have been a natural suggestion, is impossible 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.

Element 118

The collaborating teams have proposed **oganesson** and symbol **Og** for element 118. Oganesson is proposed in recognition of Prof. Yuri Oganessian (1933-) for his pioneering contributions to transactinoid elements research. 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”.

NB: This is the second time an element has been named after a living person, the first being element 106, seaborgium in 1997 [25], after transuranium pioneer Glenn T Seaborg (1912-1999).

In summary: The Inorganic Chemistry Division Committee has considered the proposals of the discoverers laboratories, and recommends 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 for elements with atomic numbers 113, 115, 117 and 118, respectively, be accepted. These provisional recommendations of the names and symbols were made available for review and comment in &&date to be inserted later & 2016. The final recommendations were approved by the IUPAC Bureau on && date to be inswerted later && 2016 as authorized by Council at its meeting of 13 August 2015. This final part of the process followed the statutory period during which the recommendations were open for public comment.

Finally, claims associated with elements have Z=119 or above are at this time not available, and the current JWP will remain “dismantled” till the time that new claims will be published that would require the re-installment of a JWP.

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. Armelado (Italy), T. Ding (China), P. Karen (Norway), R. D. Loss (Australia) D. Rabinovich (USA), T. Walczyk (Singapore/Switzerland), M. Wieser (Canada)
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