Isotope-Abundance Variations and Atomic Weights of Selected Elements: 2016 (IUPAC Technical Report)

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There are 63 chemical elements that have two or more isotopes that are used to determine their standard atomic weights. The isotopic abundances and atomic weights of these elements can vary in normal materials due to physical and chemical fractionation processes (not due to radioactive decay). These variations are well known for 12 elements (hydrogen, lithium, boron, carbon, nitrogen, oxygen, magnesium, silicon, sulfur, chlorine, bromine, and thallium), and the standard atomic weight of each of these elements is given by IUPAC as an interval with lower and upper bounds. Graphical plots of selected materials and compounds of each of these elements have been published previously. This report provides isotopic abundances, isotope-delta values, and atomic weights for each of the upper and lower bounds of these materials and compounds.

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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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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.

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On the Naming of Recently Discovered Chemical Elements—the 2016 Experience

by Jan Reedijk

In the period of 8 June to 8 November 2016, the "general" public was invited to comment on the draft document in which names and symbols for four new chemical elements were presented. In this short article, I want to sum up a few highlights illustrating that the possibility to comment on the proposed new names was widely used and has been an exciting process.

In the final document on the new names and symbols, [1] we could only acknowledge in general terms the input of so many people, varying from scientist to layman, from school kid to journalist, and from single person up to petitions of over 150 000 signatures. In this article, I would like to present some specific highlights.

According to the current practice, the President of the Inorganic Chemistry Division, in consultation with the members of the Division, considered each comment received during the five months of public review. In addition to regular email correspondence, the Division had the opportunity to debate all pertinent issues during the Division's annual meeting. The process is summarized below.

Reactions from the public

Initially, it appeared that many people and groups of people—in petitions—were proposing alternatives to the names submitted by the discoverers. This resulted from misreading the invitation to comment, or simply not liking the proposed names. Several people did not realize, or were not aware of, the fact that ONLY the discoverers can propose names and symbols; they were also unaware of the fact that the proposed names had to meet specific criteria. [2, 3] So, in responding to proposers of "alternative names", we explained that the right to propose the name of a new element is afforded to the discoverers, largely because of the enormous effort required to produce and verify the existence of a new element. Given that there are few benefits to the discoverers from this sort of science, at the very least

they can be provided the right to propose a name for the new element! This approach is fairly consistent across many areas of science, such as in the discovery of new biological species or astronomical objects.

Some of the proposed names by persons and organisations are nevertheless worth mentioning here, for historic reasons. I have classified them in a few groups:

1. Famous chemists from the past who have no element named after them, for instance Berzelius, Davy, Lavoisier, Levi, Liebig, Moseley and Ramsay. In one case, Levi, the suggestion was even accompanied by an internet petition with over 3000 professional chemists/supporters.
2. Famous musicians, like Lemmy Kilmister and David Bowie, who had passed away recently. An internet petition in favour of "Lemmium" had over 160000 "likes".
3. Famous scientists from ancient civilisations, like Razi, Biruni.
4. More general names like Luciferium, Octarine, named after a mythological concept (with an internet petition of over 50000 "likes"), or in same cases (semi) jokingly proposing names like Taxpayeron, Lazarus, Tattooine.

In addition to comments on the names for the four elements, questions were also received regarding the proper pronunciation of the names of group 17 and group 18, tennessine and oganesson. These questions could not be answered in detail given, for instance, the often-heard differences in pronunciation between American, Australian, and UK English. Additional questions were received on how to convert/translate the name tennessine into other languages and how to derive roots from it, to name their derivatives: many elements of group 17 have truncated names in other languages than English and roots are therefore not always easy to generate. Indeed, unlike elements with a name ending in "ium", the name "tennessine" cannot be automatically transferred into some other languages, since the ending –ine is not kept in these languages and is instead truncated. This was not a problem for chlorine and bromine in the past, but non-straightforward conversions have been used for iodine and astatine in some languages. In the case of tennessine, similar conversion problems and possible solutions have been brought to our attention. Some explanation may be useful; this is given in the next paragraph.

The roots of the names of the halogens are fluere (Latin) and chloros, bromos, and astatos (Greek), which in English have become fluorine, chlorine, bromine, iodine, and astatine, whereas these elements have been given shorter names in many other languages, like cloro in Spanish and Italian, Chlor in German, and chlore in French. Thus, the regular endings of group 17 elements in English are definitely not a rule in all languages. The name Tennessee, on the other hand, derives from Cherokee and the name of the village Tanasi, as explained in the literature. [4] Each language is, of course, independent in performing conversions or translations, but it is hoped that these etymological comments will be of some help when a name is to be produced, *e.g.* in Spanish, German, or French. As a matter of fact, perhaps guidelines from IUPAC could/should be offered when names and roots in non-English languages for tennessine are being asked for. That should help prevent the mistakes made in the past in some languages by incorrectly using, for example, "astatium" for the conversion of astatine.

Argumentation used in the discussion of some received comments

Not all argumentation could be included in the official recommendation for the names and symbols of the 4 new elements published in *Pure and Applied Chemistry*. [1] In fact, a few comments from the public required some discussion within IUPAC. This is particularly the case for comments on tennessine, despite the fact that the name meets all criteria. However, for this element only two straightforward 2-letter symbols were available, as Ti is already used for titanium and Te for tellurium. One was Tn. However, this symbol has been used for Thoron for decades, and is up till now still in use, in particular in the field of the *Journal of Environmental Radioactivity*, so this formerly agreed IUPAC symbol could not be used. The second and only remaining possibility for the symbol was "Ts", which as such is perfect, but as some respondents indicated, is also one of the two commonly used abbreviations for the tosyl (4-methylphenyl)sulfonyl, or p-toluenesulfonyl) group. The abbreviation Ts is, for example, mentioned in a 1996 IUPAC recommendation for carbohydrates. [5] The other abbreviation in use for tosyl is Tos, which was introduced even earlier, and used in IUPAC recommendations for nucleic acid abbreviations [6] and for amino acids. [7] The Handbook of Common Acronyms used in Synthetic Chemistry [8] has for several years mentioned both Ts and Tos as full equivalents.

Given the fact that almost any abbreviation or symbol of two letters has multiple meanings, and as this occurs often inside chemistry itself (*e.g.*, Ac as the symbol

for actinium and the abbreviations for acetyl and likewise Pr for praseodymium and propyl), the conclusion has been drawn that the context in which the element symbols are used will always make clear what the meaning is. Therefore, the chances for any confusion with abbreviations will be extremely small. The alternative, to ask the discoverers to suggest a completely new name and symbol, was considered unrealistic and undesired, and even impolite.

The Inorganic Chemistry Division was extremely pleased to receive so many different reactions from all kinds of people, groups, and countries, illustrating the great interest worldwide in the Periodic Table. It was good and pleasing to receive many reactions of agreement, but also responses that were more critical. Each respondent has received an acknowledgement of receipt, sometimes explaining the current protocol. After the final decision by IUPAC, they also received a final summary of the kind of reactions I have reported above.

Examples of Interested Youngsters

A brief summary from what two school teachers wrote is worth mentioning here. One of them wrote: "My classes read about the naming of the four newest elements to be added to the periodic table and are excited to participate in the public review process. We consider this opportunity to be a once-in-a-lifetime event. We acknowledge that the scientists that discovered the elements and the scientists at IUPAC are far more qualified to offer significant input on the names of the elements, but we wanted to convey our excitement to be part of the public review portion of the naming process. Thank you for allowing my students to contribute."

A second, most heart-warming reaction came from another school teacher, whose class of 75 students wrote individual essays. The teacher asked the students to share the name they would choose if they were allowed to name an element, and to comment on at least two of the four newly proposed names. All 75 essays were scanned, merged, and submitted as a (very large) pdf file. This has delivered me a delightful weekend's reading. Needless to say, I was pleased to learn that many of the students mentioned how proud they were to have been able to participate in these discussions. Congratulations also to their teachers!

Final remarks and Future

In closing, I want to spend some words on the future, dealing with the discovery, claiming, recognition, and naming of newly discovered elements after 2016. In the research field where the new elements are generated, no doubt nowadays the nuclear physicists do the final discoveries. However, as nicely illustrated by the discovery story of tennessine, the importance of the mutual dependence of chemistry and physics is clearly visible and emphasized. Beautiful and painstaking physics is preceded by equally beautiful and painstaking chemistry to synthesize and separate the unique target materials. So, while discovery and claiming is done in the laboratories of physicists, collaboration with chemists preparing and purifying target materials is often necessary, and thus the recognition of new elements needs to be authorized jointly by IUPAP and IUPAC. I look forward to seeing a new joint panel appointed in the not too distant future. The Periodic Table has 7 periods full of known elements. Up to the 8th period!

Finally a sentence about the naming process. Perhaps now is the time to consider offering the discoverers the many suggested names generated in the 2016 process (and from earlier/later processes) as options to consider. They could judge whether appropriate names are amongst those suggested and determine how they can serve as proposals to future discoverers. As the Periodic Table is a brand of IUPAC, the checking of names and symbols will remain an IUPAC duty, but providing a database of suggestions to those who may propose names would do no harm.

References:

1. L. Öhrström and J. Reedijk. *Pure Appl. Chem*. **88**: 1225-1229 (2016). DOI: 10.1515/pac-2016-0501
2. W. H. Koppenol, J. Corish, J. Garcia-Martinez, J. Meija, and J. Reedijk. *Pure Appl. Chem*. **88**:401-405 (2016). DOI: 10.1515/pac-2015-0802
3. J. Corish. *Chem. Int*. **38**(2):9-11 (2016)
4. Tennessee, in Encyclopaedia Britannica, 2016
5. Joint IUPAC-IUBMB Commission on Biochemical Nomenclature, Nomenclature of Carbohydrates, *Pure Appl. Chem*. **68**:1919-2008 (1996)
6. Abbreviations and Symbols for Nucleic Acids, Polynucleotides and Their Constituents, Joint IUPAC-IUBMB Commission on Biochemical Nomenclature; (1974)
7. Nomenclature and Symbolism for Amino Acids and Peptides Joint IUPAC-IUB Commission on Biochemical Nomenclature (Recommendations 1983), *Pure Appl. Chem.* **56**:595-624 (1984)
8. www.cheminform.com/acronyms

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