Names of the Heavier Elements

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There has been considerable debate and controversy regarding the names of elements with atomic numbers greater than 103. The origins of the difficulties and the eventual resolution are described in this article.

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Introduction

Although each element in the periodic table is unique due to its atomic number, it is obviously convenient to assign an appropriate name, and a symbol. One can then systematically name and represent compounds, from simple salts to coordination complexes. It is a generally accepted convention that the discoverer of an element has the honour of naming it. The inspiration often comes from (a) mythical concepts or characters, (b) place, area or country, (c) properties of the element, and (d) a scientist. Of course, the suggestion has to be ratified by the International Union of Pure and Applied Chemistry (IUPAC). Textbooks provide the recommended names and symbols for the elements up to atomic number 100. But things have not been easy with the heavier elements. This article provides an account of the many controversies, and also presents a consensus view on the most appropriate names of the elements of atomic number greater than 100.

The First Suggestions

In 1978 IUPAC decided that it is necessary to have a systematic naming for the elements with atomic number $Z > 100$, even for those which had not been discovered. The Commission on Nomenclature of Inorganic Chemistry (CNIC) suggested a procedure. It was recommended that the name should be derived directly from the atomic number of the element to be named using the following Latin numerical roots:

0 = nil	1 = un	2 = bi	3 = tri	4 = quad
5 = pent	6 = hex	7 = sept	8 = oct	9 = enn

The roots have to be put together 'in the order of the digits which make up the atomic number'. It was also decided that the name should end in 'ium' whether the element was expected to be a metal or otherwise. The final 'n' of 'enn' is deleted when it occurs before 'nil', and the final 'i' of 'bi' and of 'tri' when it occurs before 'ium'. The symbol of the element is composed of the initial *three* letters of the numerical roots, which make up the name. A typical report of a Commission, which is assigned a thankless job!

Perhaps a few examples would help understand the above recommendations. The systematic name and symbol (in parenthesis) of element 101 is unnilunium (Unu), 112 is ununbium (Uub), 150 is unpentnilium (Upn), 500 is pentnilnilium (Pnn) and 900 is ennilnilium (Enn). In several textbooks these unpronounceable names are still in use. The names of elements with $Z = 104$ to 109 in this convention are given in *Table* 1. The main advantage is that any element, whatever be the atomic number, can be named. This nomenclature is useful as a temporary arrangement till the official body IUPAC sanctifies a proper name, making reference to the history or properties of the element.

Table 1. Names of the heavier elements in different conventions (symbols are given in parentheses). (There is no controversy regarding the name of elements 101 –103: Mendelevium (Md), Nobelium (No) and Lawrencium (Lr)).

Z	IUPAC Temporary name	IUPAC old name	ACS name	Present IUPAC name
104	Unnilquadium (Unq)	Dubnium (Db)	Rutherfordium (Rf)	Rutherfordium (Rf)
105	Unnilpentium (Unp)	Joliotium (Jl)	Hahnium (Ha)	Dubnium (Db)
106	Unnilhexium (Unh)	Rutherfordium (Rf)	Seaborgium (Sg)	Seaborgium (Sg)
107	Unnilseptium (Uns)	Bohrium (Bh)	Nielsbohrium (Ns)	Bohrium (Bh)
108	Unniloctium (Uno)	Hahnium (Hn)	Hassium (Hs)	Hassium (Hs)
109	Unnilenium (Une)	Meitnerium (Mt)	Meitnerium (Mt)	Meitnerium (Mt)

Discovery of Elements Beyond 100

The elements discovered in the early part of chemistry were generally isolated from naturally occurring sources. In contrast, the heavier elements are all synthesized by nuclear reactions. Enrico Fermi and E O Lawrence made many new elements using two alternative approaches [1]. Fermi created many elements by bombardment of light projectiles, like neutrons, on target nuclei, resulting in the formation of an unstable isotope. Through β-emission, the element with the next atomic number is formed. A typical example is the formation of neptunium from uranium:

[1] E Fermi and E O Lawrence were awarded the Physics Nobel Prize in 1938 and 1939, respectively. Their names are associated with two major laboratories and also two transuranic elements.

$$^{238}_{92}\mathrm{U} + ^{1}_{0}n \xrightarrow{-\beta} ^{239}_{93}\mathrm{Np}$$

The alternative approach is to use a heavy ion accelerator to fuse two nuclei. A typical example is the synthesis of element with $Z = 107$ (mass number 262) by fusing chromium-54 and bismuth-209, with the loss of a neutron.

By the above methods, the periodic table has been extended by almost 20%. While some of the elements can be produced, isolated and stored in large quantities, all of the transuranic elements are highly radioactive. Many of them have very short half-lives. As a result, only a few atoms of some of these heavier elements have ever been observed (*Box* 1, *Table* 2).

Box 1

To give a broad idea of 'occurrence' of heavy elements, plutonium is available in ton quantities, curium in kilogram amounts, and einsteinium in milligrams. In contrast, only 29 atoms of the element 107 with mass number 262 and 3 atoms of element 109 have ever been observed.

It is evident that a great deal of effort is needed to make these heavier elements. A lot of team effort is involved. Expensive equipment is to be used. Even if a new element is made, proving its existence is not an easy task. As a result, the 'discoverer(s)' would prefer to have the prerogative of naming the new elements and not call them after plain numbers.

There are three major laboratories continuing the efforts on synthesizing new elements in a systematic way. These are the Lawrence Berkeley Laboratory (LBL), California (USA), Joint Institute of Nuclear Research (JINR), Dubna (Russia) and Gesellschaft für Schwerionenforschung (GSI), Darmstadt (Germany). One can recognize the potential for controversy

Z	Mass number	Half-life [ms]	Fused nuclei	Number of atoms observed	Time of discovery
107	262	8.2	^{209}Bi and ^{54}Cr	14	February 1981
		106.0		15	
	261	9.0		9	
108	265	1.8	^{208}Pb and ^{58}Fe	3	March 1984
109	266	3.4	^{209}Bi and ^{58}Fe	3	August 1982
110	269	0.17	^{208}Pb and ^{62}Ni	4	November 1994
	271	1.1		9	
111	272	1.5	^{209}Bi and ^{64}Ni	3	December 1994

Table 2. Details of discovery of some of the heavier elements.

right away. At different periods of time, each of these laboratories claimed discovery of a new element and went ahead with coining a name of its choice. But often, the claims were disputed. To make matters worse, the competing teams claimed successes of their own, and would offer alternative names. The situation became increasingly unmanageable.

Compounding of the Problem

In 1985 the Transfermium Working Group (TWG) was set up under the joint auspices of the International Union of Pure and Applied Chemistry (IUPAC) and the International Union of Pure and Applied Physics (IUPAP) to look into the problem of priority of discovery of the elements with nuclear charge number $Z > 100$. The two Unions selected the members of the group consisting of nine scientists in nuclear physics and chemistry in 1987. The primary objectives of this international group, headed by Denys Wilkinson, was to formulate criteria for the discovery of a new element to be recognized, and to determine priority of discovery among the various competing groups on this basis. The group met seven times for approximately one week each, three of the meetings being in the laboratories of the three major groups concerned. The TWG group in close consultation with these laboratories established general criteria that must be satisfied for the discovery of a new element. This part of their work was accepted by IUPAP and by IUPAC. The other painstaking work of the group was to critically review all the pertinent literature in this area and find out the *discovery profiles* of the transfermium elements in chronological order. The conclusions, duly endorsed by IUPAC and IUPAP, were published in 1993.

IUPAC invited responses on the last two TWG reports from the three concerned laboratories. The JINR group at Dubna and GSI group at Darmstadt appreciated the effort of the TWG in developing criteria for the discovery of a new element to be recognized. But the response by Albert Ghiorso and Glenn T Seaborg from LBL was the longest and most critical. It was stated that 'the report is riddled with errors of omission and commission'. The serious disagreement was regarding the claim to the discovery of element 104 that was attributed to JINR at Dubna in the TWG report. They also did not agree with the TWG conclusion that the Berkeley and Dubna work on the discovery of element 105 'was essentially simultaneous'. However they seemed to agree with the TWG report on the discovery of element 106 which states that the Dubna group '...does not demonstrate the formation of a new element with adequate conviction, whereas that from Berkeley–Livermore does'. They took serious note of rescheduling of the meeting of Dubna investigators who were last to meet with the TWG group and 'having the last word'. In essence the Berkeley scientists did not agree with most of the TWG report and condemned it for not seeking the advice of several experienced nuclear chemists.

However, it was not the task of the TWG group to recommend names for new elements, which rests with the IUPAC Commission on Nomenclature of Inorganic Chemistry (CNIC). The Commission consisting of twenty scientists, all with equal voting

The most contentious issue in the controversy is the recommendation that an element should not be named after a living person. Americans strongly opposed this idea.

rights, met in Balatonfüred (Hungary) on 31st August 1994 to consider the naming of the transfermium elements 101–109. The Commission decided to accept the TWG report as one of the bases for selecting names. The three major groups involved in the discoveries had also been asked for their proposals and the reasons for their choices. It resolved unanimously to continue the practice of naming elements 'after appropriate scientists, places and properties'. Interestingly, it agreed (16 to 4 votes) that an element *should not be named after a living person*. Finally the CNIC recommended a set of names (*Table* 1) for the elements 101–109 with a fair degree of consensus among its members. The above recommendations were accepted unanimously by the IUPAC Bureau at its meeting in Antwerp (Belgium) on 17th–18th September 1994. However the recommendations were subjected to ratification by the IUPAC Council meeting which was scheduled to meet at Guildford (UK) on August 1995.

However, the LBL teams from California chose to rebel. They announced at a press conference that they would recommend that element 106 should be named after their former leader Glenn T Seaborg, *who is very much alive*. The CNIC recommendation of not naming an element after a living person received a strong reaction from the Berkeley group. It is to be noted here that CNIC decided to name 106 after Rutherford. The LBL group had originally proposed the name 'rutherfordium' for element 104. The CNIC recommended name for 104 was 'dubnium', which was in appreciation of the work done in this area by JINR at Dubna.

The overall situation deteriorated further when the American Chemical Society (ACS) refused to accept the recommendation of CNIC. The names approved by ACS are also given in *Table* 1. Much of the outcry was over the rejection of 'seaborgium' for element 106. Although IUPAC's recommendations carry greater weight, they have no binding force and the ACS is in a position to adopt whatever nomenclature it wishes in the journals and papers under its influence.

Current IUPAC Nomenclature

The IUPAC Bureau met at Guildford (UK) in September 1995 to decide on the recommendation of CNIC. As a result of the growing criticisms and emotional debates, the Bureau decided to adopt the CNIC recommendations *as provisional*. It also invited several organizations and individuals to express their views concerning the extant proposals for the names of these elements. Reportedly, the response from the general chemical community was small, and the bulk of the replies came from nuclear scientists. The commissions reconsidered all the names at a meeting in Chestertown, Maryland (USA) in August 1996 and recommended a *new* set of names for the elements 104–109. It accepted the fact that the final decision of naming a new element should be taken by CNIC, and ultimately has to be confirmed by the Interdivisional Committee on Nomenclature and Symbols, Bureau, and Council of the Union. It also recognized the fact that the discoverers have the traditional right to propose a name, and such suggestions must receive serious consideration. The Commission reiterated its acceptance of the TWG report as a basis for their new recommendations. But after spitting fire at the dissenters, the Commission also decided to *modify* TWG decision that the name of a living scientist should not be used as a basis for an element name!

In the new recommendations, the elements 101, 102 and 103 retained their commonly accepted names 'mendelevium' (Md), 'nobelium' (No) and 'lawrencium' (Lr), respectively. The name 'seaborgium' for 106, proposed by its discoverers, was accepted. It was decided that GSI at Darmstadt and JINR at Dubna should jointly share the honor of discovery of element 107. The claims of discoveries of element 108 and 109 by the Darmstadt laboratory are uncontested. The discoverers of elements 107, 108 and 109 proposed the name 'nielsbohrium', 'hassium' and 'meitnerium', respectively. The Commission accepted the last two. The name 'nielsbohrium' for element 107 'is long and includes the first name of Niels Bohr as well as his family name'. There is no such

It has been estimated that 500 more isotopes remain to be discovered.

precedent. The Commission preferred the name 'bohrium' after consulting with the Danish National Adhering Organization (NAO).

The naming of elements 104 and 105 were the subject of vigorous debate. Both the Berkeley and Dubna groups claimed priority. The Commission accepted the name 'rutherfordium' for element 104 to honor the New Zealand nuclear physicist, Ernest Rutherford. It was also of the opinion that the Dubna laboratories had 'played a key role in developing the experimental strategies used in synthesizing several transfermium elements', and recommended that element 105 should be named 'dubnium' in its honor. The present IUPAC names for the elements beyond proton number 100 are given in *Table* 1.

Concluding Remarks and Outlook

Is the naming controversy just a storm in a teacup? After all, the transfermium elements are rarely seen in common scientific journals. Their chemical properties are almost never studied because only a very few number of atoms have ever been created and observed. The answer lies in the fact that we must be prepared for future scientific development in this area. It is quite plausible that many interesting chemical discoveries may be made with these elements. Seaborg has even suggested that systematic investigations should be carried out on the huge stockpiles of nuclear wastes ('a priceless treasure', in his words) stored in his country and elsewhere.

The problem of nomenclature of elements is by no means over. Many more elements beyond $Z = 110$ remain to be discovered. Theoretical physicists have predicted the existence of many such heavy elements. Elements with a set of atomic numbers have even been suggested to lie in an 'island of stability'.

For example, the GSI group at Darmstadt has synthesized elements 110 and 111 by fusing two heavy nuclei.

$^{62}Ni + ^{208}Pb \rightarrow ^{269}110 + 1n$ Date: 09 – 11 – 1994

$^{64}Ni + ^{208}Pb \rightarrow ^{271}110 + 1n$ 19 – 12 – 1994

$^{64}Ni + ^{209}Bi \rightarrow ^{272}111 + 1n$ 17 – 12 – 1994

The same group has also produced and unambiguously identified element 112. The isotope with mass number 277 of this element has been observed on irradiation of 208–Pb targets with 70–Zn projectiles.

No names have been given to elements 110, 111 and 112 so far. It may be an interesting exercise for the readers to work out the temporary names of these elements following the rules based on numerals mentioned earlier.

Suggested Reading

[1] G Herrmann, *Angew. Chem.*, Int. Ed. (Engl.), Vol. 27, 1417, 1988.

[2] G T Seaborg, *Acc. Chem. Res.*, Vol. 28, 257, 1995.

[3] *Pure & Appl. Chem.*, Vol. 69, 2471, 1997.

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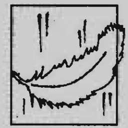

Element 114 Synthesized

The successful synthesis of element 114 has been reported a few weeks ago. If confirmed, this would represent the element with the highest atomic number known so far.

Rumford's chance observation of the movement of the tiny particles of dust up and down the thermometer tube gave him the clue to the transfer of heat in liquids. Particles of the hot liquid rise in the containing vessel because they are lighter (less dense) than the colder particles. When they reach the cold surface they descend because the cold air has cooled them. This transfer of heat by the movement of particles is called convection.

Before Rumford discovered this, most scientists believed that heat was transferred in liquids, as it is in solids, by a process known as conduction. For example, when one end of a copper rod is heated, the particles become hot and heat the particles next to them, and so on until the heat has passed all the way along the rod although none of the particles has moved. Count Rumford's observations had led him to prove that liquids are bad conductors but good convectors of heat.

Stories from Science IV