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Review

Row 7 of the periodic table complete: Can we expect more new elements; and if so, when?

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ABSTRACT

In this perspective the impact of the completion of the 7th row up to $Z = 118$, by the addition of four new elements in the periodic table – nihonium, moscovium, tennessine and oganesson – is described. Also the methods of how to "synthesize" new chemical elements, and the methods and difficulties of verifying such new elements are briefly discussed. Some speculations are presented about possible new element discoveries in the coming years.

Finally, the pathway of how the IUPAC names of the new elements are determined, are presented and illustrated by the most recent 4 additions of new elements.

Contents

1. Introduction and history

At the end of 2015, IUPAC (International Union of Pure and Applied Chemistry) and IUPAP (International Union of Pure and Applied Physics) have officially recognized the discovery of 4 new elements [1,2] and by the end of 2016 IUPAC has published their names and symbols [3]; this decision was ratified at the July 13 World Council meeting of all IUPAC country members, while meeting in Sao Paulo. The first reports of the synthesis of these elements go back 10–15 years as detailed in the validation papers [1,2]. This implies that the process of verification is time consuming and – as illustrated below – requires a very careful, even painstaking process.

Ever since the introduction of the first periodic tables by Meyer and Mendeleev just before and in 1867 [4,5] with some 50–60 elements known, and who both received the Royal Society Davy Medal for this discovery in 1882 [6], new elements have been added continuously (see below).

The Periodic Table (System) was discovered in an era when atomic structures and electrons were not known and equipment to purify and separate elements was still primitive. The discoveries of Mendeleev, Meyer and others are therefore to be seen as immense. After the first International Conference of Chemists in 1860 (Karlsruhe) which both Mendeleev and Meyer attended, it became clear that a number of scientists had noted some regularities between chemical elements. The discoveries published in 1869 by Mendeleev, first in a vertical order, later that year in a horizontal arrangement, were preceded by discoveries of similar "regularities"

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from Béguyer de Chancourtois, Newlands, Odling, Hinrichs and Lothar Meyer [4,5]. Only Meyer produced a quite similar tabular arrangement, in fact just after Mendeleev. There is general acceptance that Mendeleev published his system noting that there was a periodic classification, i.e., the periodic law and the systematic arrangements of the elements, including some of the not yet discovered elements for which he even predicted chemical properties. That some of these predictions were incorrect and that in his system there was no place for the Noble Gases, still make him the generally accepted chief architect, since he discovered the "system"; only later it was changed to "Table" as we now use in the Periodic Table of Elements. Remarkaby, the word "System" is still used as in "Periodic System" in a number of languages, e.g., Danish ("Periodiske system"), Dutch ("Periodiek systeem") and German ("Periodensystem"), just as Mendeleev and Meyer did in their papers.

Even before the latest four additions to the Periodic Table [3], speculations had been published about the possible end of the Periodic Table [7], most recently followed by a detailed web-based discussion, at the Smithsonian Magazine [8]. The most significant increase in the previous century no doubt has been the extension of the actinide series by Seaborg in 1940s [9–12], which has resulted into a Noble Prize award in 1951.

$$^{209}\text{Bi}\ (Z{=}83) + {}^{70}\text{Zn}\ (Z{=}30) \rightarrow {}^{278}\text{Nh}\ (Z{=}113) + \text{neutron}$$

$$^{243}\text{Am}\ (Z{=}95) + {}^{48}\text{Ca}\ (Z{=}20) \rightarrow {}^{288}\text{Mc}\ (Z{=}115) + \text{neutrons}$$

$$^{249}\text{Bk}\ (Z{=}95) + {}^{48}\text{Ca}\ (Z{=}20) \rightarrow {}^{294}\text{Ts}\ (Z{=}117) + \text{neutrons}$$

$$^{249}\text{Cf}\ (Z{=}97) + {}^{48}\text{Ca}\ (Z{=}20) \rightarrow {}^{294}\text{Og}\ (Z{=}118) + \text{neutrons}$$

Scheme 1. Examples of reaction equations for the synthesis of the 4 new elements.

Given the very difficult process of proving newly discovered elements, a very careful protocol has been in use by IUPAC and IUPAP for a number of decades now. This process describes recognition of the assignments of the new elements, after detailed verification, and how to arrive at names and symbols for these new heavy chemical elements [13]. This whole process has been summarized in an overview by John Corish [14]. With the upcoming recognition and name giving of elements 117 and 118, which would belong to group 17 and 18 of the Periodic Table, also the rules for name giving had been updated in 2016 [15], so that names from these groups will all end in "-ine" (group 17), or "-on" (group 18). It should perhaps be noted here that the classification of a newly discovered element in a group is determined by the *Z* number and column structure of the Periodic Table. This would not imply chemical properties resembling the elements higher in the column. Relativistic effects do play a role and the heavier the involved elements the more pronounced such relativistic effects will be.

2. New element generation and discussion

After the gradual filling of the Periodic Table up till uranium (element 92), synthetic elements were gradually added and they were usually made from bombardment of the heaviest elements with neutrons, or with helium nuclei. In this way, more heavy nuclei were added in the so-called cold fusion process [9–12].

In a long special-issue article of Chemistry World, Yuri Oganessian and others have been interviewed by Kit Chapman, and in that article a full description of all aspects of new-element synthesis is presented, including the so-called island of stability and the sea of instability [16].

In theory, any collision of two nuclei may generate a new element. This was known already for decades by experiments of

Fig. 1. Picture of the wall of the chemistry building in Murcia Spain.