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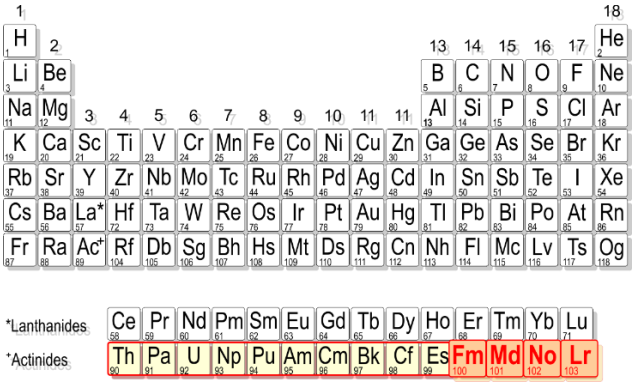
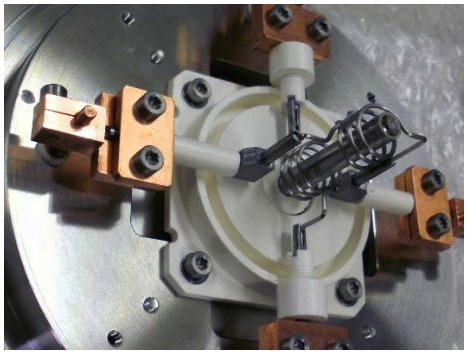
First Ionization Potentials of Fm, Md, No, and Lr: Verification of Filling-Up of 5f Electrons and Confirmation of the Actinide Series

In a current paper in the Journal of the American Chemical Society (JACS), a collaboration led by scientists at the JAEA Tandem accelerator in Tokai with key contributions by the Group of Prof. Dr. Christoph Düllmann reports on the first ionization potentials of the heavy actinides, fermium (Fm, atomic number Z = 100), mendelevium (Md, Z = 101), nobelium (No, Z = 102), and lawrencium (Lr, Z = 103).



Current Periodic Table. The position of the studied elements at the end of the actinide series is highlighted. (© B. Schausten, GSI)



The surface ion source: grey tantalum tube in the image center, surrounded by two heating filaments. It is installed at JAEA Tokai, Japan (© JAEA)

The first ionization potential (IP_1) is the energy required to remove the most weakly bound electron from a neutral atom and is a fundamental property of any chemical element. The IP_1 values were determined in an atom-at-a-time regime using a method based on a surface ionization process in a tantalum ionizer, coupled to an online mass separation technique. The efficiency of the surface ionization process depend directly on the IP_1. The measured IP_1 values agree well with those predicted by state-of-the-art relativistic calculations performed alongside the present measurements. The value measured for No also agrees well with the laser spectroscopic work carried out at GSI in the group of Prof. Dr. Michael Block.
Similar to the well-established behavior for the lanthanides, the IP_1 values of the heavy actinides up to No increase with filling up the 5f orbital, while that of Lr is the lowest among the actinides. These results clearly demonstrate that the 5f orbital is fully filled at No with the $[Rn]5f^{14}7s^2$ configuration and that Lr has a weakly bound electron outside the No core. In analogy to the lanthanide series, the present results unequivocally verify that the actinide series ends with Lr.
The experiment was led by collaborators at JAEA Tokai, Japan, where it was carried out at the JAEA Tandem accelerator, in collaboration with international partners including experimenters from the Institute of Nuclear Chemistry of Johannes Gutenberg University Mainz.