

3-1 Discrepancy in the Periodic Table Appears at Element 103

— Successful Measurement of the First Ionization Potential of Lawrencium, Element 103 —

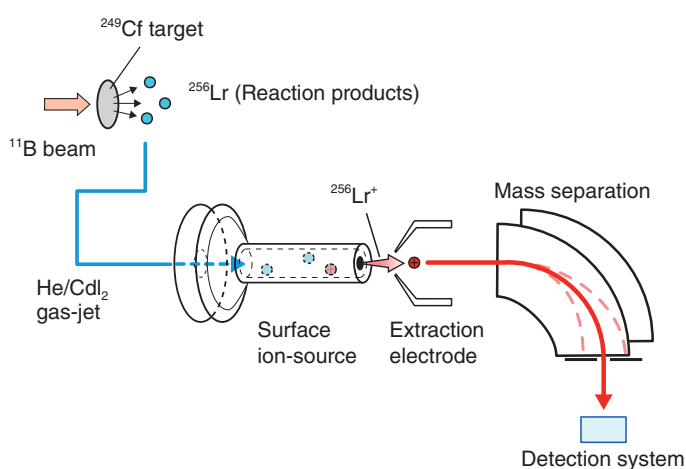


Fig.3-2 Schematic of the experimental set-up

Short-lived ^{256}Lr produced in the nuclear reaction was transported to a surface ion-source by a He/CdI_2 gas-jet transport system and then ionized. Produced ions were extracted and mass-separated. The amount of ions collected after the mass-separation was determined to calculate the ionization efficiency of ^{256}Lr . The first ionization potential (IP_1) of Lr can be calculated based on the ionization efficiency.

The periodic table shows the periodicity of the chemical properties of elements. In the heaviest element region, however, it is expected that chemical properties may differ from those extrapolated from lighter homologs.

Heavy elements ($Z > 100$) can be produced in nuclear reactions using an accelerator. Their chemical properties have not been sufficiently investigated because of their low production rates and short half-lives. The first ionization potential (IP_1), one of the most fundamental physical and chemical properties of an element, gives direct information about the binding energy of an electron in the outermost electronic orbital of an atom. Accurate IP_1 values for heavy elements provide crucial tests for our understanding of their electronic structure.

In this study, we measured the IP_1 value of lawrencium (Lr, element 103) with a novel method we have developed based on the dependence of ionization efficiency on IP_1 in the surface-ionization process wherein an atom is ionized via interaction with a solid surface at a high temperature.

The isotope ^{256}Lr (half-life 27 s), produced in the reaction $^{249}\text{Cf}(^{11}\text{B}, 4n)$, was ionized on a tantalum surface at 2500 °C. An ionization efficiency of ^{256}Lr was determined by measuring the radioactivity of ^{256}Lr after mass separation following

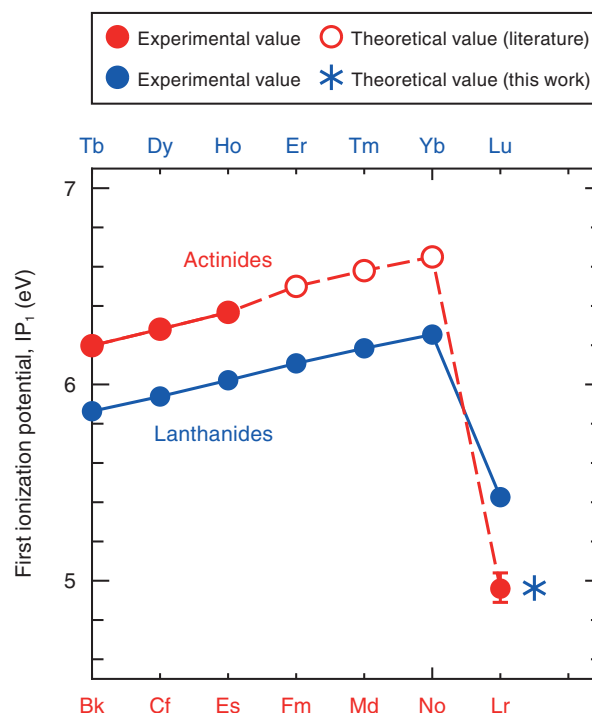


Fig.3-3 The first ionization potential (IP_1) of heavy lanthanides (●) and actinides (●), including our present results for Lr

Lr has the lowest IP_1 among actinide elements like Lu in lanthanides. This indicates that Lr is the last member of the actinide series.

the ionization (Fig.3-2). This work was performed at JAEA Tandem Accelerator Facility.

From the obtained ionization efficiency, we successfully evaluated the IP_1 value of Lr to be $4.96^{+0.08}_{-0.07}$ eV for the first time. This IP_1 value is the lowest one among those of all actinide elements and comparable to that of sodium (5.1391 eV), an alkali metal. Changes of the IP_1 values of actinide and lanthanide elements with atomic number are shown in Fig.3-3. In the heavy lanthanide series, the IP_1 value increases monotonically up to ytterbium (Yb) with the atomic number and then suddenly decrease at lutetium (Lu), the last lanthanide element. Our experimental result shows that Lr has the lowest IP_1 like Lu. This indicates that Lr would be the last member of actinides.

A state-of-the-art theoretical calculation for Lr IP_1 was also performed. The theoretical value is in pretty good agreement with the experimental one. This agreement strongly suggests that the electronic configuration of the Lr atom, which characterizes the chemical properties of Lr, would differ from that expected based on the periodic table.

The results of this study are expected to yield a better understanding of the chemical properties of actinide elements.

Reference

Sato, T. K. et al., Measurement of the First Ionization Potential of Lawrencium, Element 103, *Nature*, vol.520, issue 7546, 2015, p.209–211.