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Mass measurements on neutron-deficient Sr and neutron-rich Sn isotopes with the ISOLTRAP mass spectrometer

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Abstract

The atomic masses of ^{76,77,80,81,86,88}Sr and ^{124,129,130,131,132}Sn were measured by means of the Penning trap mass spectrometer ISOLTRAP at ISOLDE/CERN. ^{76}Sr is now the heaviest $N = Z$ nucleus for which the mass is measured to a precision better than 35 keV. For the tin isotopes in the close vicinity of the doubly magic nucleus ^{132}Sn, mass uncertainties below 20 keV were achieved. An atomic mass evaluation was carried out taking other experimental mass values into account by performing a least-squares adjustment. Some discrepancies between older experimental values and the ones reported here emerged and were resolved. The results of the new adjustment and their impact will be presented.

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1. Introduction

Experimental values for the ground state binding energy and the excitation schemes of doubly magic nuclei and their neighboring nuclides form the basis of all shell model calculations. ^{132}Sn is the only link between the two stable doubly-magic nuclides ^{56}Ni ($N = 28$, $Z = 28$) and ^{208}Pb ($N = 126$, $Z = 82$). Shell model calculations based on the properties of ^{132}Sn make predictions on all nuclides in the region between the proton shells $28 < Z < 82$ and the neutron shells $50 < N < 126$. This area contains about half of the nuclides which are known today and the majority of very neutron-rich nuclides, which are relevant for the astrophysical r-process. Whereas all necessary data around the two benchmarks ^{56}Ni and ^{208}Pb are available since long, and shell model predictions are in perfect agreement with them, still no sufficient measurements exist for ^{132}Sn and the close vicinity around it. Another main issue in each nuclear theory, the description of shell closure and its disappearance for exotic nuclei, the so-called shell quenching [1,2], requires data on the binding energies of unstable, magic nuclei. As the number of valence nucleons increases, the shapes of the nuclei tend to turn from a spherical configuration (doubly-magic) to extreme deformations. Particularly, the $N \approx Z$ nuclei have been of special interest since the early days of investigating the structure of atomic nuclei [3,4]. Following the concept of valence nucleons and mirror nuclei this region is still a unique test bench for investigating the forces between individual nucleons as well as their interactions with the residual nuclear core [5,6]. Furthermore, strong deformations among the upper fp-shell $N \approx Z$ nuclei have particularly triggered development of new methods for deducing the nature of ground-state deformations [7,8]. It is of central relevance whether the theoretical predictions remain valid when extending them into formerly unknown regions far from the valley of β-stability. The very heavy $N = Z$ nuclei are of additional importance due to their key role in the astrophysical rp- (rapid proton capture) process [9] and their close vicinity to the proton drip line. Also here a key quantity allowing the comparison of theoretical models and measured values is the ground state binding energy, and hence the atomic mass.

In the last decade, great progress both in the production and preparation of exotic nuclides [10] as well as in the improvement of mass-measurement techniques [11] was achieved. Until now all values for ground state binding energies of nuclei around ^{132}Sn were based on the Q_β-values of complete β-decay chains, spanning from the valley of stability to the investigated nuclide. The mass measurements reported here were performed using the Penning trap mass spectrometer ISOLTRAP [12] at the on-line isotope separator ISOLDE [13] located at CERN in Geneva, Switzerland. Here the mass determination is linked to the measurement of the cyclotron frequency $\nu_c = qB/(2\pi m)$ of an ion being confined in a Penning trap. This frequency governs the motion of an ion with charge q and mass m circulating in a magnetic field of strength B. Thus, for a known charge state the mass can be determined by measuring the cyclotron frequency ν_c and the magnetic field B. In the following the experimental setup of the ISOLTRAP mass spectrometer is explained and the mass measurements for the nuclides ^{76,77,80,81}Sr and ^{129,130,131,132}Sn are described. The results are compared with literature values and their influence on the surrounding mass surface is discussed.