Schottky Mass Spectrometry of Cooled ^{197}Au Fragment Beams in the ESR ◇

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The Schottky noise of ions stored in the experimental storage ring ESR of the GSI was used for mass measurements of ^{197}Au fragments. For a description of the Schottky-mass-spectrometry-setup at ESR see [1,2] and the references therein. We present here the results of precise Schottky Mass Measurements [3]. The primary ^{197}Au-beam was accelerated in the UNILAC and SIS to 930 A*MeV, and passed through a 8 g/cm^2 ^{9}Be-target. The projectile fragments (with energies of 330 - 370 A*MeV) were separated by the fragment separator FRS and then injected into and stored in the ESR. There the mixture of the various nuclei in different ionic charge states (q = Z, Z-1 and Z-2) with roughly the same m/q-values was cooled by electrons to the same velocity. By changing the m/q setting of the FRS and ESR the composition of unknown and reference nuclei in one Schottky frequency spectrum was altered systematically.

Thus, a "mass surface" of the nuclear chart was scanned over a large range and with high precision and efficiency.

The masses were determined by measuring 10 kHz wide Schottky spectra and using a linear relation between the m/q-values and the measured frequencies [3]:

$$\frac{f - f_0}{f_0} = -\alpha_p \frac{(m/q) - (m/q)_0}{(m/q)_0},$$

where α_p is the so called momentum compaction factor, which is a machine parameter. If there are at least two isotopes with known masses, we can determine the momentum compaction factor. The formerly unknown masses can be determined by applying the above formula with this α_p and using one of the known masses as reference. The mass values of the reference peaks were taken from the Audi/Wapstra tables [4], and for the corrections of these atomic masses to the measured masses of the ions we used tabulated values from [5–7].

During the three days ^{197}Au-beam time, the masses of 115 neutron deficient isotopes in the range from Yb to Hg were directly measured [3]. And by using the Q-values of α-decay chains the masses of additional 20 isotopes in the range from Pt to Po could be determined. The masses of 53 isotopes were not known before, and we got improved mass values (smaller errors) for 14 isotopes. We achieved mass values with errors of

$$\sigma_M = (120 - 150)\ \mathrm{keV}/c^2,$$

and a mass resolution of

$$\Delta M/M \geq 3 \times 10^{-6}.$$

This corresponds to a mass resolution of ≥600 keV in the examined region. Some of the isotopes, whose masses have been measured, have isomers with half-lives as long or even longer than the measuring time with an energy difference to the ground state of less than 600 keV. Therefore the selection of the reference peaks in the spectra is limited to the mass peaks which do not have a known isomeric state with the above mentioned qualities.

A consistency check was done by comparing the mass values, that we have achieved with different charge states of one isotope in different FRS-ESR settings. I.e. the mass values of one isotope are determined in different charge states with different reference peaks. For two of the known α-decay chains we measured the masses of more than one isotope of the chain. Therefore we performed another consistency check of the measurements by using the measured masses to calculate the Q_α-values and comparing them with the literature values. Those comparisons show a good agreement for the masses of one isotope in different charge states and between the mass differences and the Q_α-values [3].

Finally, we used the determined masses for testing the accuracy of different mass models [8,9] and the extrapolated values of Audi/Wapstra [4]. The conclusion of this test is, that the extrapolated values of Audi/Wapstra are the best mass values for the formerly unknown masses. Only if there are no mass values in the Audi/Wapstra tables one should use the mass predictions of the finite range droplet model [9].

References

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