First Extraction Measurements with the Cryogenic Gas Stopping Cell at SHIPTRAP*

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One of the open questions in modern nuclear physics is the existence and the exact location of the so called 'Island of Stability' of superheavy elements. The evolution of the nuclear binding energy close to the region of the superheavy elements, an indicator of nuclear stability, can be obtained by high-precision mass measurements. Recently, the masses of $^{252-255}$No [1] and ^{255,256}Lr [2] were directly measured for the first time with the Penning-trap mass spectrometer SHIPTRAP. From the results the strength of the deformed shell closure at neutron number N = 152 has been determined experimentally.

To extend the reach of SHIPTRAP towards superheavy elements it is crucial to increase the overall efficiency of the setup. The bottleneck is the deceleration of the fusion-evaporation reaction products from SHIP from a kinetic energy of MeV down to meV in a gas stopping cell. Thus, a second generation gas stopping cell (CryoCell) operating at cryogenic temperatures was built as described in detail in [3]. An increase of the overall efficiency by at least a factor of 5 [4] is anticipated.

In August 2012 the first measurement of the extraction efficiency was performed with a ^{223}Ra (half-life 11.43 days) recoil ion source. Figure 1 shows the alpha spectrum obtained in vacuum to determine the initial activity of ^{223}Ra. Afterwards, the source was placed axial symmetrically in front of the largest ring electrode of the RF-Funnel inside the CryoCell. From there, the recoil ions, *i.e.* ^{219}Rn$^+$ (half-life 3.96 s), are extracted. The number of extracted ^{219}Rn$^+$ ions was determined with a silicon detector placed behind the extraction radio-frequency quadrupole (RFQ). The ^{219}Rn recoils were accumulated on an aluminium foil with a thickness of 0.8 μm at -1400 V positioned in front of the detector. Direct implantation of the ^{219}Rn$^+$ ions would corrupt the result. Due to its noble gas configuration a major fraction of the extracted ions would diffuse out of the silicon detector before the decay occurs. The resulting alpha spectrum looks similar to that shown in Fig. 1 however without the lines of the ^{223}Ra decay. The number of ^{219}Rn$^+$ ions detected behind the Extraction RFQ is compared to the number of ^{219}Rn$^+$ recoil ions emitted by the ^{223}Ra source that can be derived from the initial activity. Taking into account the exponential decay of the initially determined activity of ^{223}Ra and the solid angle covered by the silicon detector the extraction efficiency was calculated. The measurement was performed at room temperature and at 40 K. A similar buffer-gas flow (1 mbar·l·s^{-1}) of ultra pure helium (purity 99.9999 %) was used which corresponds to a pressure of 60 mbar at 300 K and 21 mbar at 40 K, respectively. DC-gradients of 7 V/cm at the DC-Cage, 2 V/cm at the RF-Funnel and 0.2 V/cm at the Extraction RFQ were applied. RF amplitudes of 160 V at the RF-Funnel for a frequency f = 1014 kHz and 240 V at the Extraction RFQ (f = 907 kHz) were used. At room temperature a maximum extraction efficiency of 37(3) % was obtained. The extraction efficiency increased to 64(3) % as the system was cooled to 40 K. The operation at cryogenic temperatures, *e.g.* the increased buffer-gas cleanliness, result in a relative gain in transmission efficiency of 75 % compared to the operation at room temperatures. An experiment with a radioactive ion beam, directly delivered by SHIP, will be performed soon to confirm this promising result that will pave the way towards high-precision mass measurements of superheavy elements at SHIPTRAP.

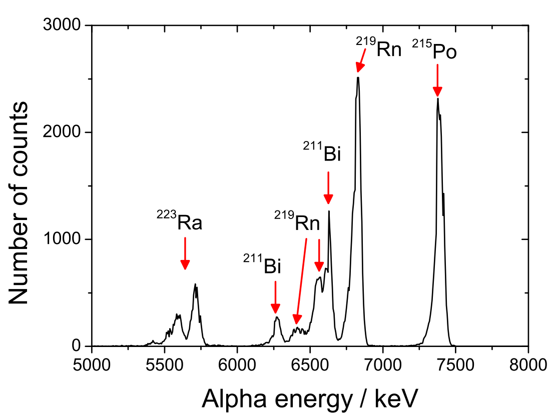

Figure 1: Alpha-decay spectrum obtained in 3600 s with a ^{223}Ra recoil ion source.

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