Development of a Drift-Time Spectrometer for Superheavy Elements ◇

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The element specific electron configuration of ions directly reflects the quantum mechanical observables $< r^2 >$ and r_{max}, which denote the expectation value of the electron density and the principle maximum of the wave function of the outermost electron orbital, respectively. These observables can be determined by ion-mobility measurements [1], which may present - in combination with mass number A analysis - a new access to element identification of Superheavy elements.

The ionic mobility K is determined by measuring the drift time of ions in a homogenous electric field inside a buffer gas cell. Using already the most simple rigid sphere model for collisions between ions and buffer gas atoms, ionic radii can be inferred from the collision cross section, which is inverse proportional to K [2]. Considering the low production rates (< 1/min) of single, Superheavy ions, the use of an ultra-sensitive setup for ion-mobility measurements similar to that described in Ref. [3] is necessary.

Fusion reaction products produced at the UNILAC accelerator at GSI in Darmstadt will be separated from the primary beam with the gas filled separator TASCA [4] and stopped as singly charged ions inside the gas-filled drift-time spectrometer at an argon pressure of about 100 mbar. The ions are guided by a static electric field towards a nozzle (diameter $d = 1$ mm) and are extracted with the buffer gas jet. After separation of the ions from the gas jet in a differential pumping section, the ions will be mass analyzed in a quadrupol mass filter and detected with a channeltron detector, which determines the detection time t_2. The drift time of the ions is given by $t_{drift} = t_2 - t_1$, whereas t_1 is the time when the ions are stopped in the buffer gas. t_1 can be inferred from the drift-time differences of the heavy ions and the buffer gas ions, which are created during the stopping process of the fusion products.

A suitable drift-time spectrometer with 21 ring electrodes is being developed. Its total length amounts to 35 cm. The extraction side of the electrode system is characterized by a decreasing inner diameter of the electrodes for focusing of the ions through the exit nozzle, see Fig. 1.

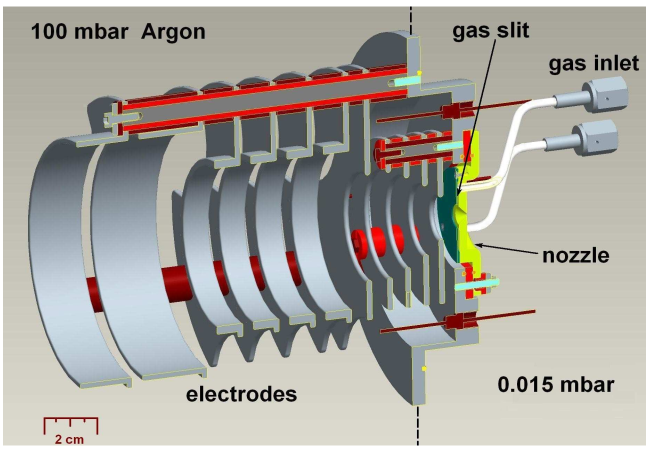

Fig. 1: Cross-section plot of the ion-mobility spectrometer for Superheavy elements. Only the extraction part is shown.

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The electrode system has been optimized for ion-mobility measurements with a resolution of $\frac{\delta K}{K} < 1\%$, necessary for the observation of changes in the ionic radii. Due to the non-vanishing width of the conducting nozzle, all ions are guided onto this electrode if they arrive at a distance $> d/2$ from the axis of symmetry, see Fig. 2. This is the dominant fraction of the ions transported from the stopping region. The trajectories of $^{254}No^{+1}$ ions shown in the same figure, demonstrate the defocusing effect resulting from pure electrostatic forces disregarding the gas flow. Therefore the gas inlet system is designed such that the gas flow causes additional focusing of the ions at the nozzle and consequently enhances their extraction efficiency. The gas provided from three gas inlets passes a 0.5 mm narrow slit, which is part of the nozzle and causes a homogenous gas flow into the nozzle throat. Figure 2 shows a contour plot of the radial gas velocities at the nozzle obtained from the computer code for gas-dynamic simulations FLUENT 6.2 [6]. According to the simulations, radial gas velocities > 10 m/s with a focusing effect for the ions are achieved at the slit exit. The closer the ions drift toward the nozzle throat, the stronger becomes the gas focusing mechanism. At the nozzle throat the friction force in the emerging buffer gas jet dominates the ion motion and the ions are extracted out of the buffer gas cell. First off-line experiments at long-lived actinides are planned within this year.

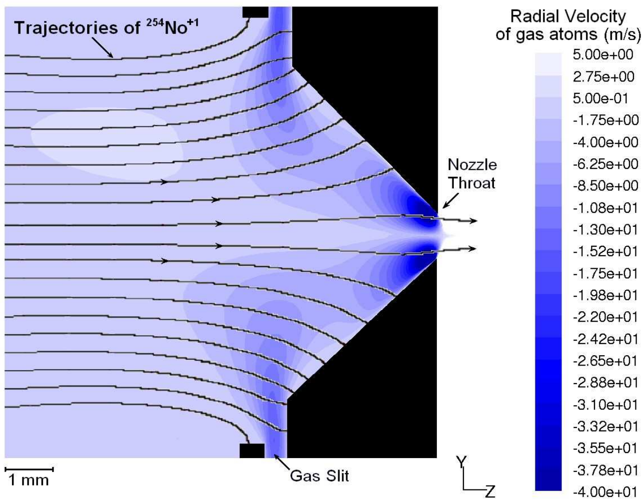

Fig. 2: Contour plot of the radial gas-velocities of argon at a gas flow rate of ca. 14 mbar l/s at the nozzle. Negative velocities indicate focussing versus the axis of symmetry. Trajectories of $^{254}No^{+1}$ ions were simulated with *SIMION* [5].

References

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