Drift Time Measurements in a Buffer-Gas Cell

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The aim of this project is the investigation of atomic properties of trans-einsteinium elements (Z > 99) in a buffer-gas cell. Of particular interest are measurements of ionic radii and bond length of simple molecular ions. Drift time measurements with which the ion mobility and in turn the ionic radii can be determined may present a direct access to investigate the increasing importance of relativistic effects for these heavy elements.

To explore the prospects for such experiments, drift time measurements of $^{243}Am^+$ and $^{239}Pu^+$ were performed in an off-line buffer-gas cell. Am and Pu atoms were evaporated from an electrically-heated filament containing both elements and were subsequently ionized by laser resonance ionization [1]. The photo ions drift in a suitable electric field towards the nozzle of the cell and are flushed out by the buffer-gas jet. With the aid of a segmented linear Paul trap and skimmers the ions are separated from the buffer-gas jet, mass selected in a quadrupole mass spectrometer and detected with a channeltron detector. To form simple molecules a reaction gas like O_2 can be admixed to the argon buffer-gas. The time between laser pulse and detection in a channeltron detector is dominated by the ion drift in the electric field of the gas filled optical cell.

In Fig. 1 drift time spectra of Am^+ and Pu^+ are plotted. Between plutonium und americium a drift time difference of (0.07 ± 0.02) ms was measured at a drift time of (1.88 ± 0.01) ms. This corresponds to a relative contraction of the ionic radius of americium compared to the ionic radius of plutonium of (3.1 ± 1.3)%. For the atomic radius of americium compared to plutonium, relativistic calculations predict a contraction of same magnitude [2]. However no calculations for ionic radii exist at present. From the measured drift time of plutonium, (1.85 ± 0.01) ms, and plutonium oxide, (2.38 ± 0.01) ms, see Fig. 2, an increase of the ionic radius of plutonium oxide compared to plutonium of (28 ± 2)% was determined [3].

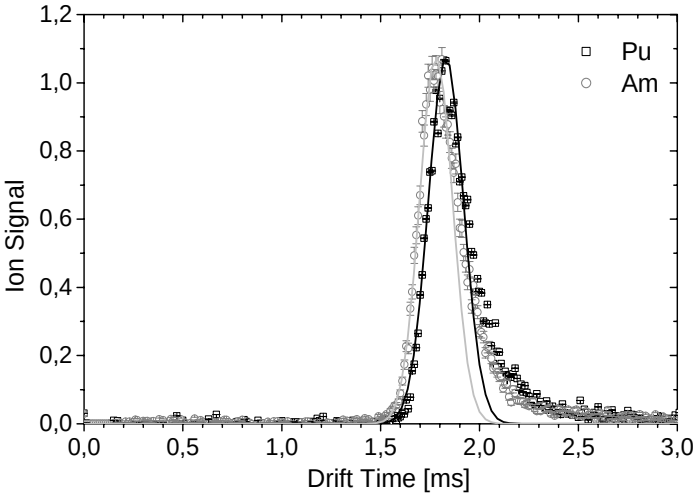

Figure 1: Drift time spectra of $^{243}Am^+$ (gray) and $^{239}Pu^+$ (black). To determine the drift time, a Gaussian was fitted on the leading edge of the ion signal. Laser ionization takes place at t=0.

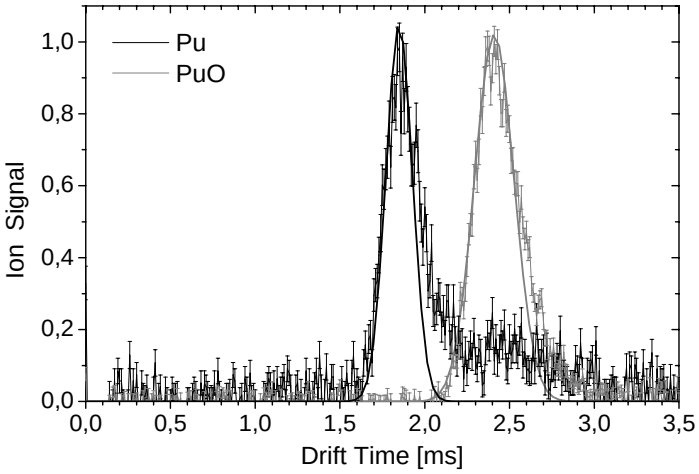

Figure 2: Drift time spectra of Pu^+ and PuO^+. Laser ionization takes place at t=0.

A contraction of same order has also been observed in previous experiments between Cf+ and Fm+, performed in the same buffer-gas cell [4,5].

Furthermore, a break up of AmO+ to Am+ + O was observed. Obviously, this reaction occurs at the nozzle. A systematic investigation as function of the accelerating electric field would allow to determine also the bond energy of these oxides.

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