Chemical Reactions of Erbium Ions in a Buffer-Gas Cell

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The aim of this project is the investigation of ion-chemical reactions of transeinsteinium elements (Z>99) in the SHIPTRAP buffer-gas cell. Stopped singly charged ions of heavy elements as, e.g., ^{254}No or ^{256}Lr can react with admixtures to the inert buffer gas like O_2, H_2O, or CH_4. The reaction products are extracted from the cell by means of electrical fields and mass-analyzed in a quadrupole mass spectrometer. The changes of reaction constants in a group of chemical homologues may provide detailed information on the electronic structure of valence electrons of the heavy elements. The method is being developed and tested for the element erbium (Z=68), which is the chemical homologue of fermium (Z=100).

It is important to show that reaction constants can be measured in an inert buffer gas atmosphere with sufficient precision. As a prerequisite, precise reaction constants must be known under well-defined experimental conditions [1]. Therefore, in a first step various ion-chemical reactions of erbium ions were examined in a Fourier Transform Ion Cyclotron Resonance Spectrometer (FT-ICR) [2]. In the second step the same reactions were investigated in the buffer-gas cell. 50 MeV Er^{7+} ions from the MP tandem accelerator facility at the MPI-K Heidelberg were implanted in the gas cell which was filled with 60 mbar argon. Ions were created from the fraction of erbium thermalized as atoms by laser resonance ionization. The reaction gas, O_2 or CH_4, was added to the buffer gas by glass capillaries. The mass spectra of the extracted erbium and erbium-products were detected by a quadrupole mass filter. The reaction time t is the drift time of the ions in the gas cell and amounts to (2.1 ± 0.2) ms, see fig.1. The ratio of erbium ions to the sum of ions and reaction products $Er^+/(Er^+ + ErO^+)$, taken from the mass spectra, as a function of the reaction gas pressure p is shown in figure 2.

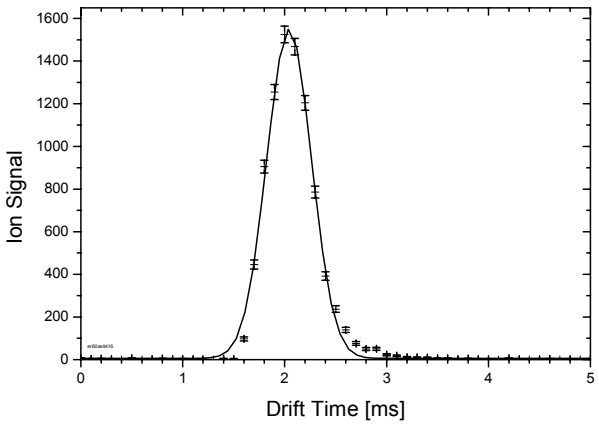

Figure 1: Drift time of erbium ions in the buffer-gas cell. Laser ionization occured at t=0. The full line represents a best fit by a Gauß function.

A reaction constant of $k_{O2} = (3.3 \pm 0.4)\cdot10^{-10}$ cm^3 / (molecule·s) was determined for the reaction $Er^+ + O_2 \rightarrow ErO^+ + O$ which is in agreement with the value $(3.6 \pm 0.3)\cdot10^{-10}$ cm^3 / (molecule·s) as determined with the FT-ICR spectrometer [2].

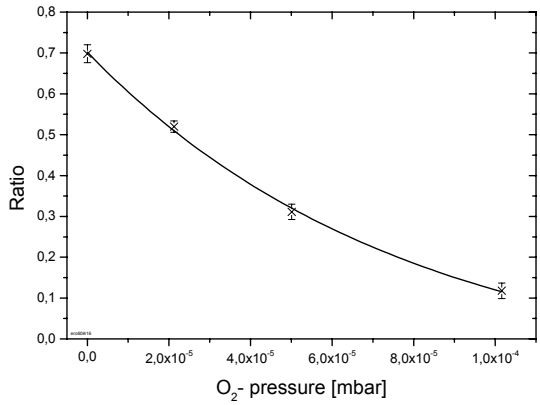

Figure 2: Measured $(Er^+/(Er^+ + ErO^+))$ ratio as function of the O_2 reaction gas pressure. The full line represents a best fit by an exponential function with a reaction constant k = (3.3 ± 0.4)·10^{-10} cm^3 / (molecule·s).

The reaction $Er^+ + CH_4 \rightarrow ErCH_2^+ + H_2$ has not been observed, since it is energetically forbidden. This result is in agreement with our FT-ICR measurements [2] and also with ref. [3].

Erbium ions created by laser resonance ionization at rather long times after the slowing down process are expected to react in a surrounding which has the temperature of the buffer-gas cell since resonance ionization causes only a small energy transfer to the ion. However, that fraction of ions which came to rest as ions directly after the slowing down process are expected to be located in a hot thermal spot. The latter originates from the energy transfer to the buffer gas at the end of the ion trajectory. Consequently, the reaction constant may be altered. A corresponding reaction constant measurement failed. Obviously, sensitive parameters like space charge in the buffer gas created by the primary ions could not got fully under control.

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