Ion Chemical Reactions with Heavy Elements in the Gas Phase

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The aim of this project is the investigation o fion-chemical reactions of trans-einsteinium elements (Z>99) in the SHIPTRAP buffer-gas cell. Stopped singly charged ions of heavy elements as e.g. ^{254}No or ^{256}Lr will react with admixtures to the inert buffer gas as e.g. 0_2, H_2O, or CH_4. The reaction products are extracted from the cell with the aid 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 for the element erbium (Z=68) which is the chemical homologue of fermium (Z=100). In a first step it must be shown 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 [l]. This has been achieved by examining ion-chemical reactions of erbium ions with 0_2, CH_4, and C_4H_8, (butene) in a Fourier Transform Ion Cyclotron Resonance Spectrometer (FT-ICR). Experiments for the measurement of the same reactions in a buffer-gas cell are under way. As a first step, the Er+ ions will be created by evaporation of Er atoms from a filament and subsequent laser resonance ionization. In the last step of the preparatory experiments, the reaction constants will be measured after implantation of 50 MeV $\underline{\mathrm{Er}}^{7+}$ ions from the MP tandem accelerator facility at the MPI-K Heidelberg.

[l] A. Dretzke et al,, Hyp. Interact. **132** (2001), 501

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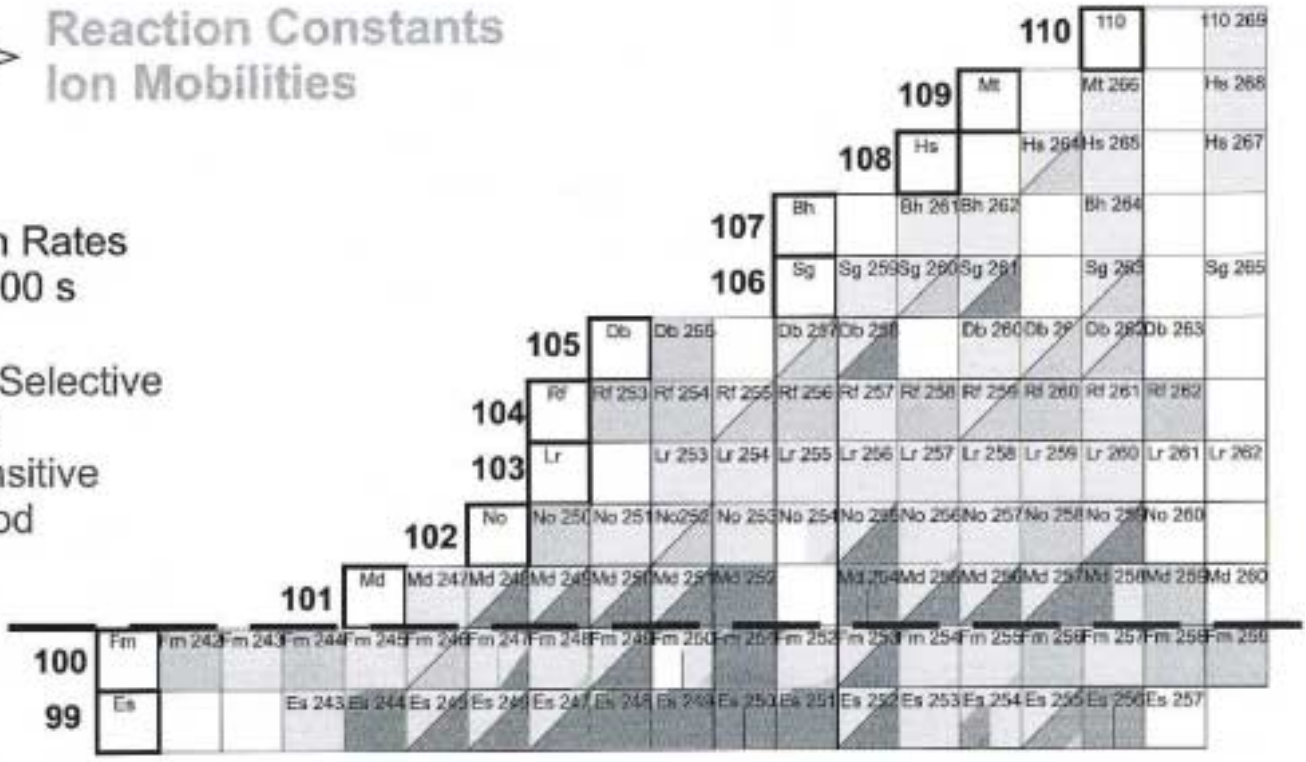
Reaction Constants
Ion Mobilities

Production Rates
$\dot{N}$ = 1/100 s

Direct Mass Selective
and
Ultra-Sensitive
Method



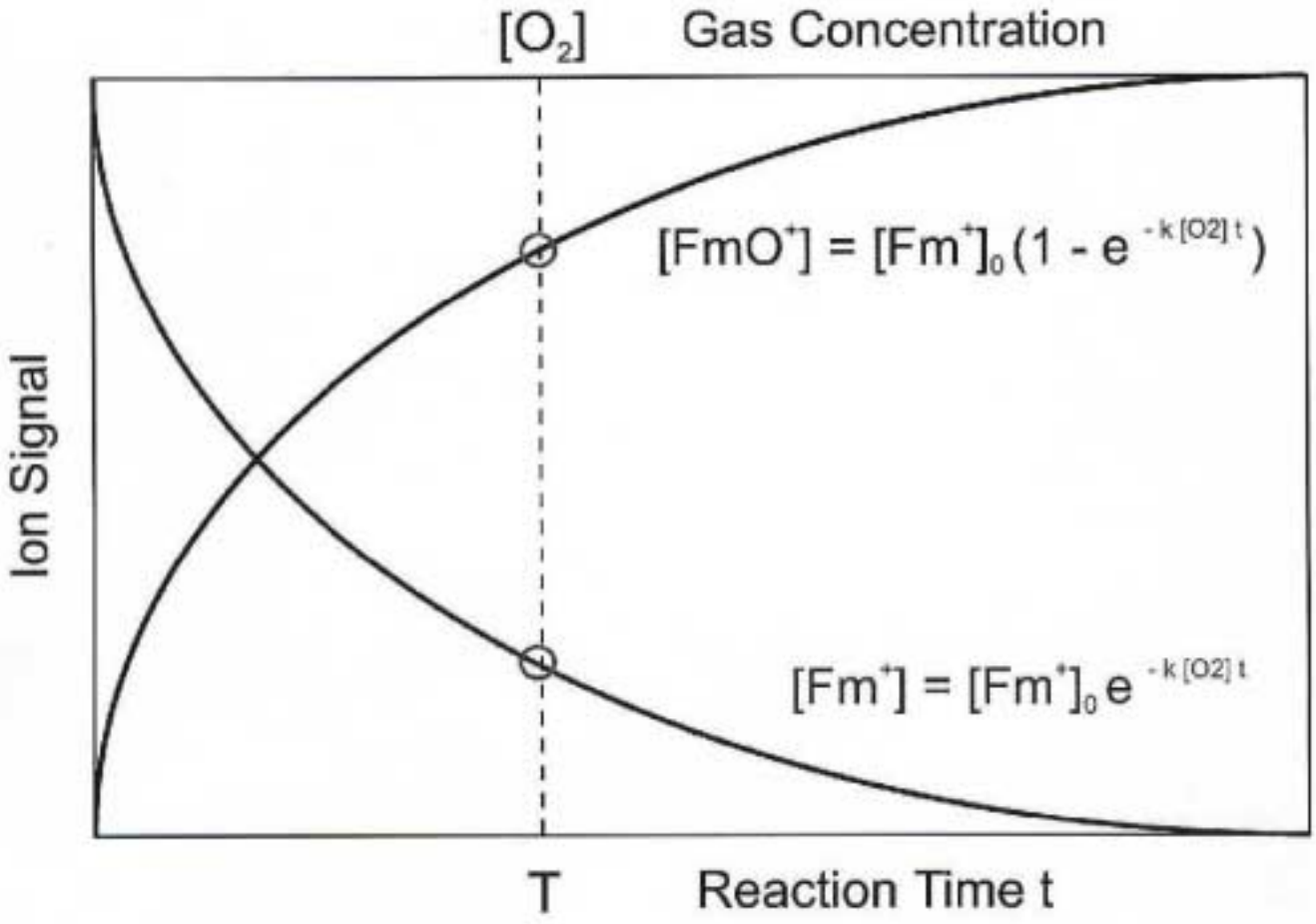
Gas-Phase Reactions with Transactinides

Transactinides: Fm, Md, No, Lr...
Homologues: Er, Tm, Yb, Lu...
+
Reaction gases:
O_2, H_2, H_2O, CO_2, Methan, Ethan...

$$Fm^+ + O_2 \longrightarrow FmO^+ + O$$

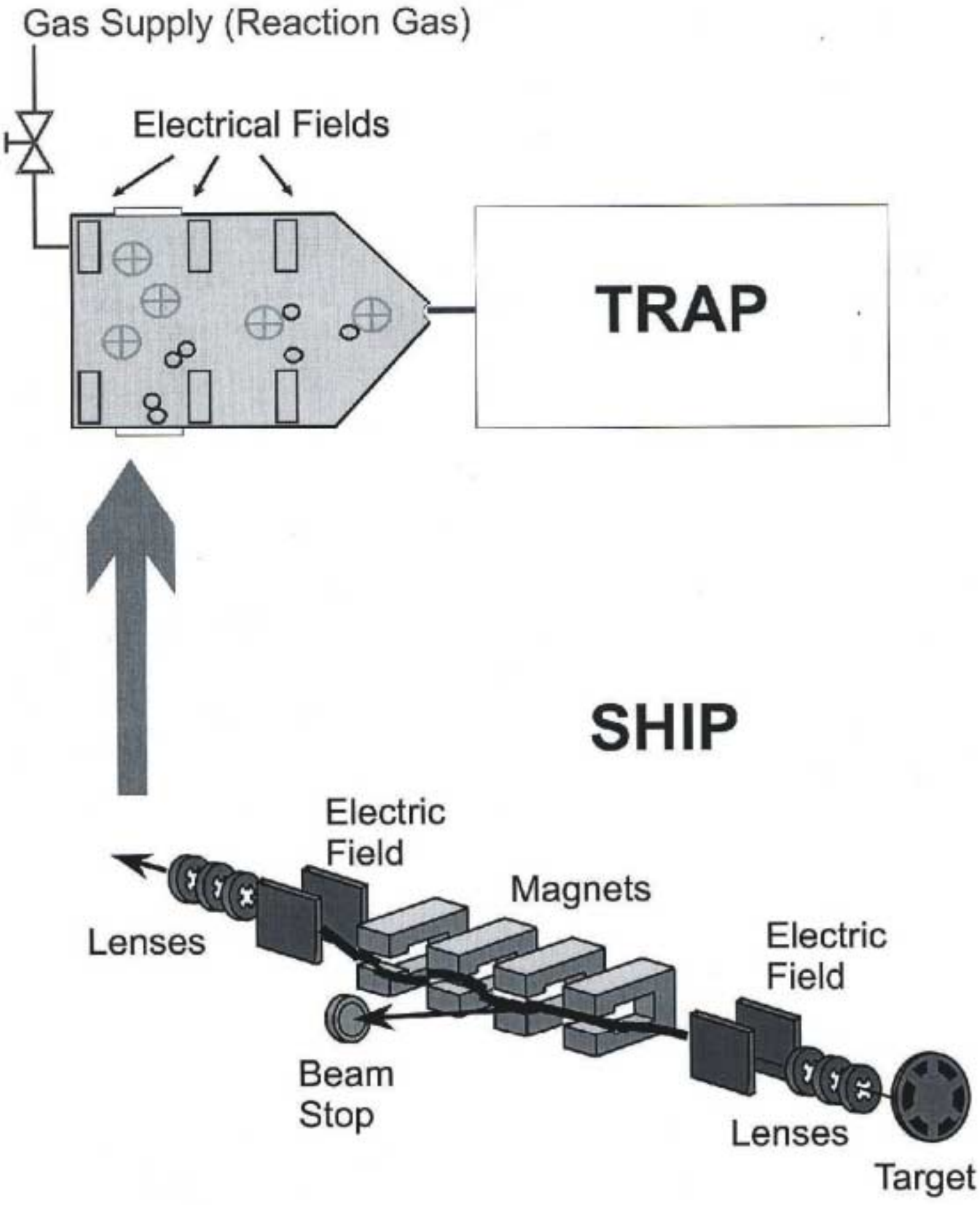
Reaction constant k, defined by:

$$- \frac{\partial [A^+]}{\partial t} = k [A^+] [XY]$$



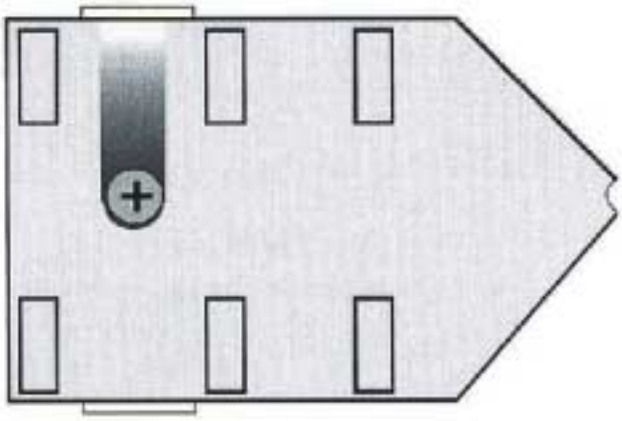
$[A^+]_0 = [AX^+] + [A^+]$ at any time

Ion Chemical Reaction Studies at SHIPTRAP



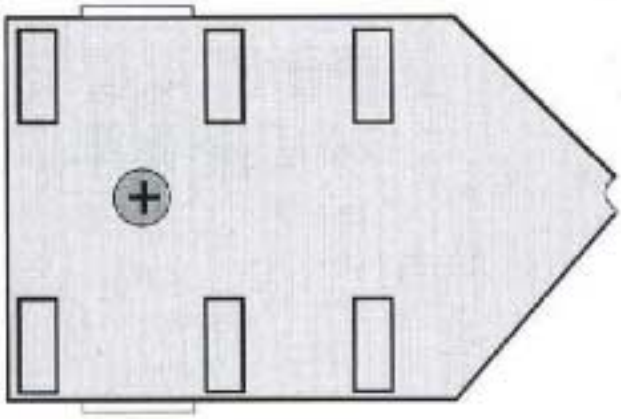
Ion Production Mechanisms

Buffer Gas Cell



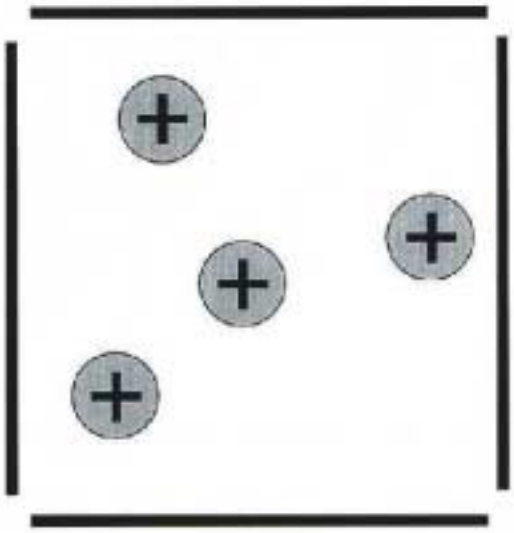
'hot' sourrounding

direct implantation
bragg-peak -> hot spot



'cold' sourrounding

FT / ICR

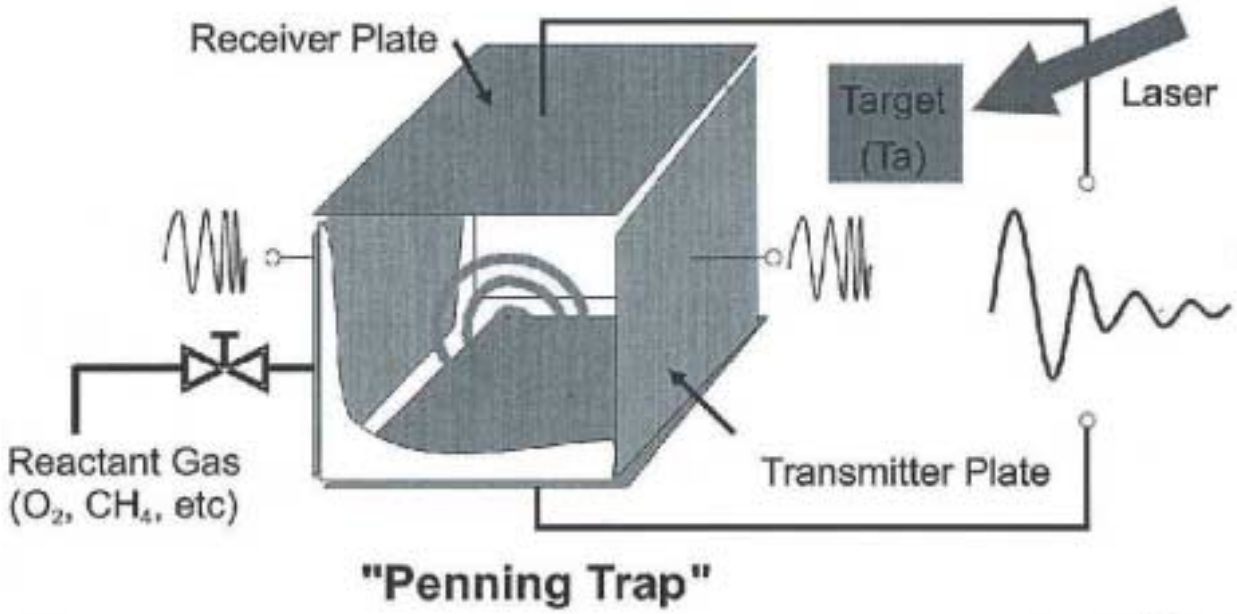


low pressure

only reaction gas at low pressures

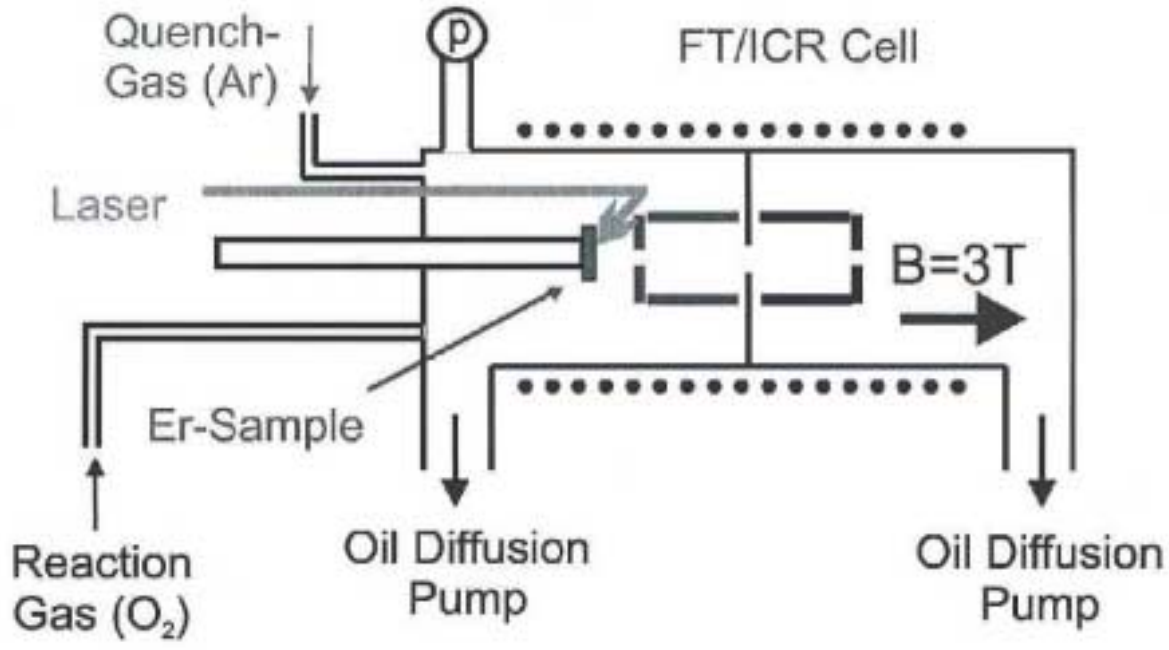
FT-ICR Measurements

$$Er^+ + O_2 \longrightarrow ErO^+ + O$$

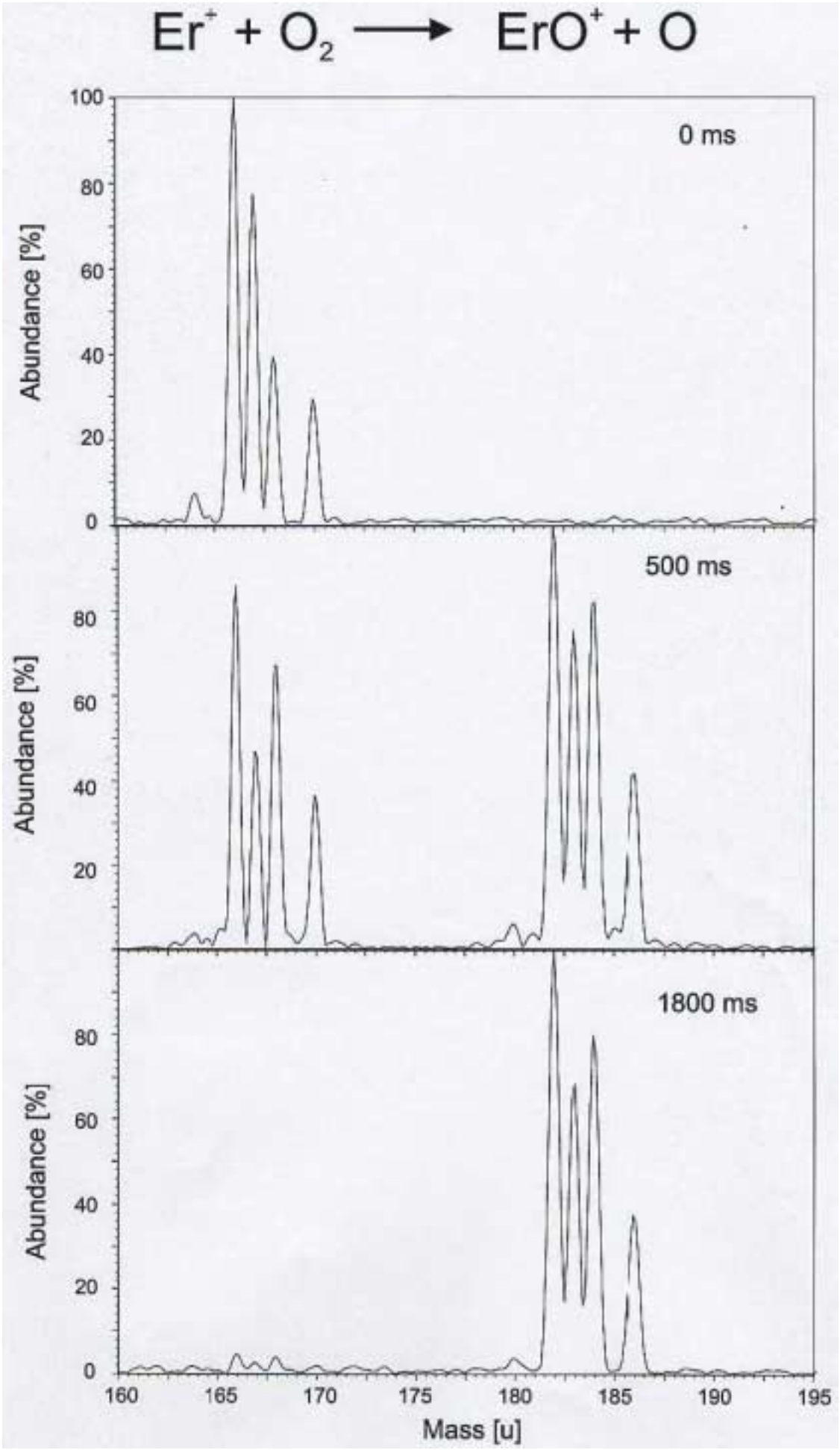


"Penning Trap"

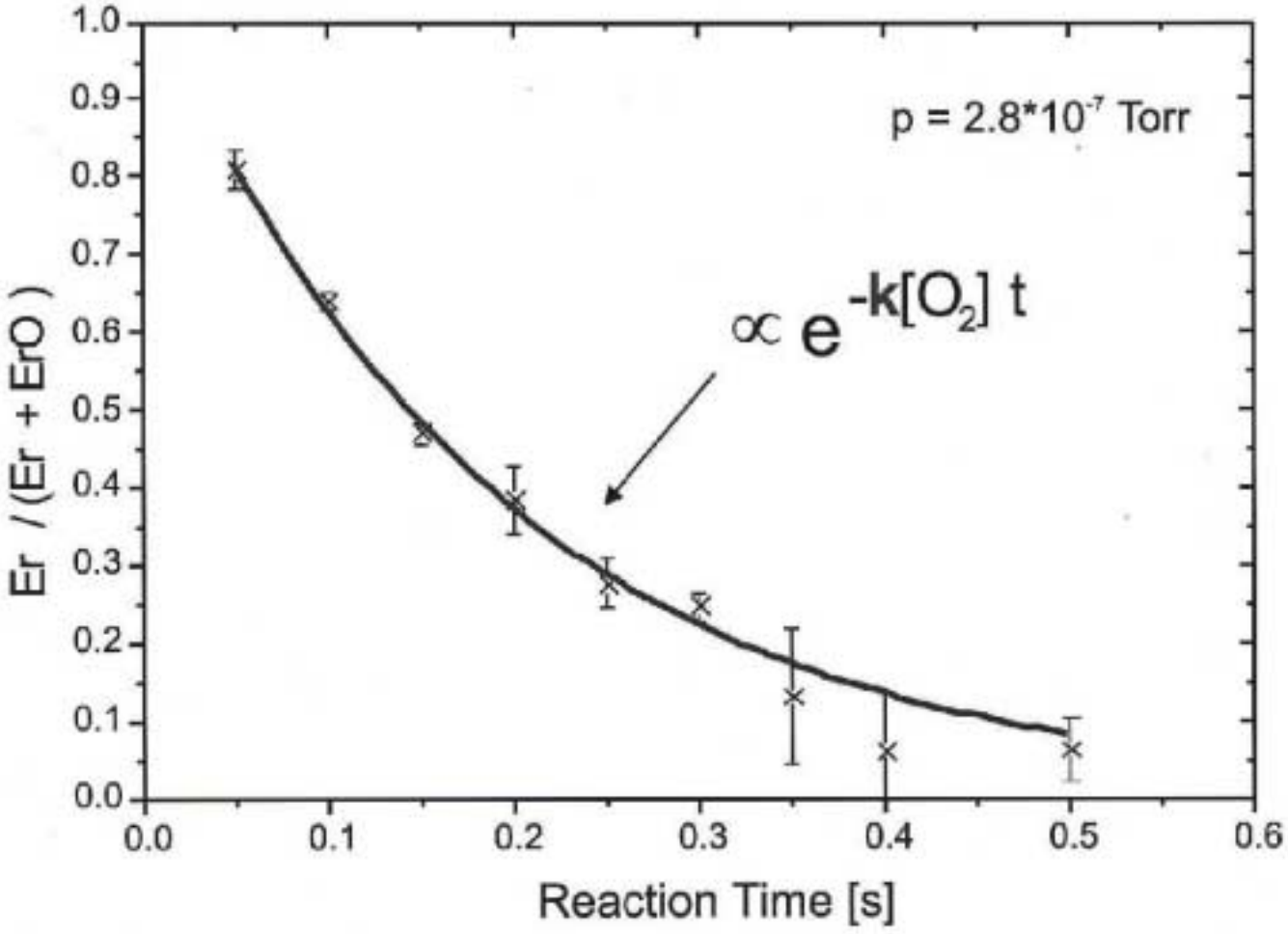
$$\omega_c = q/m\ B$$



Fourier Transform Mass Spectrometer **(EXTREL FTMS 2001)**


$Er^+ + O_2 \longrightarrow ErO^+ + O$
0 ms
500 ms
1800 ms
Abundance [%]
Mass [u]
0
20
40
60
80
100
160
165
170
175
180
185
190
195

Exponential Decay of the Er^+ to (Er^+ + ErO^+) Ratio



$$k = (3.6 \pm 0.3) \cdot 10^{-10}\ cm^3\ molecule^{-1}\ s^{-1}$$

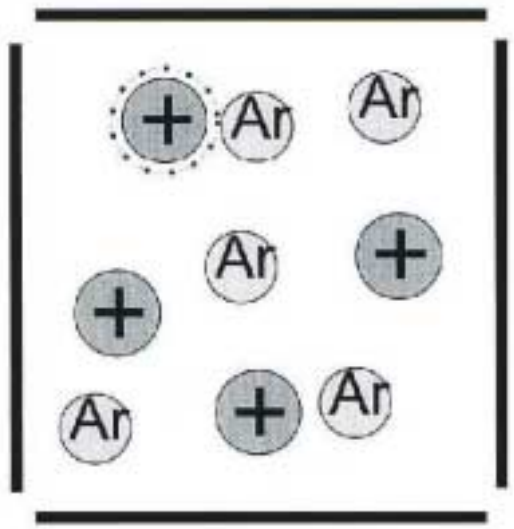
$k_{lv} = 5.7 \cdot 10^{-10}\ cm^3\ molecule^{-1}\ s^{-1}$
(Langevin Capture Cross Section)

$$\frac{k}{k_{lv}} \sim 0.63$$

→ Access to Activation Energy Measurements

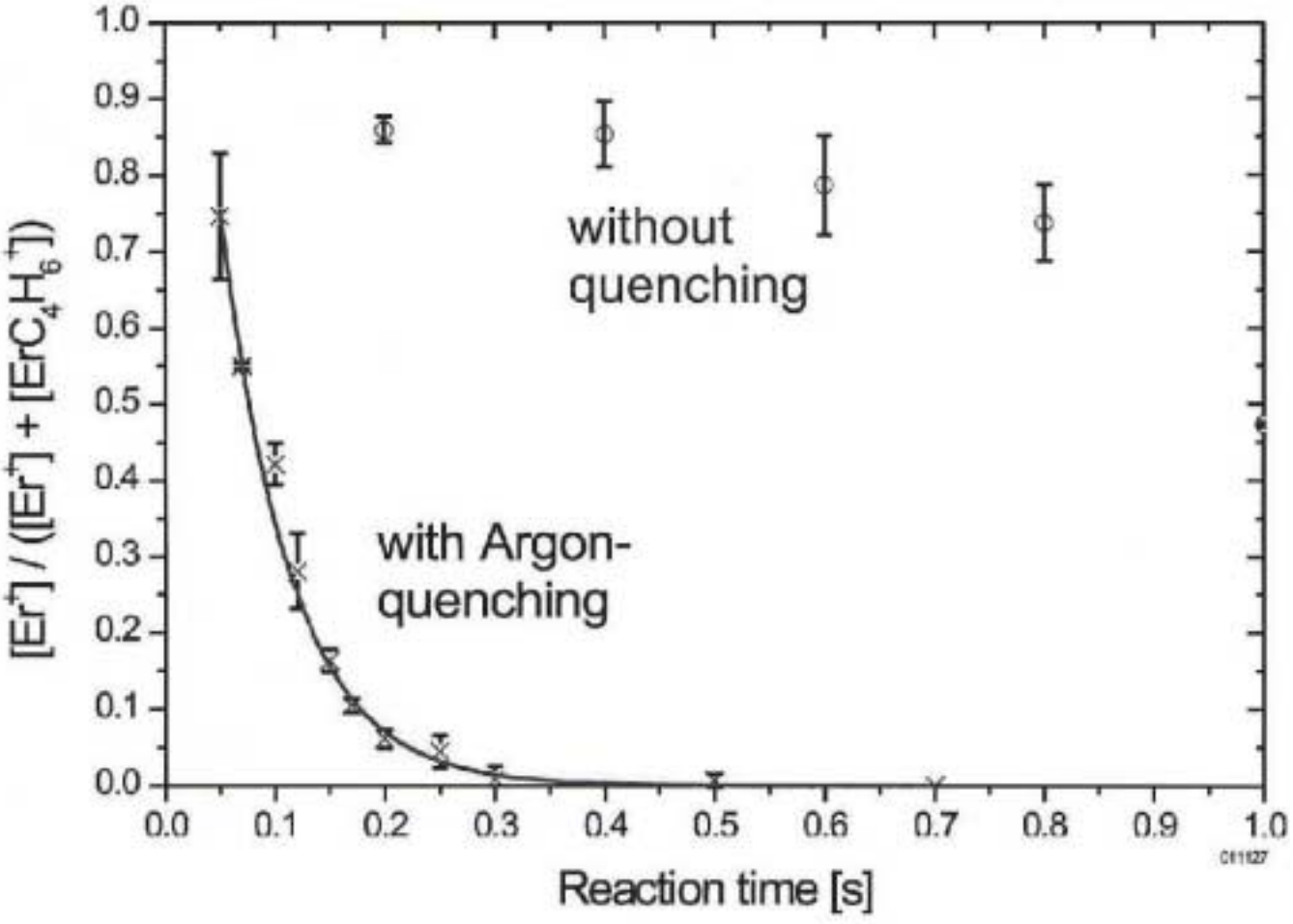
Erbium + Butene

$$Er^+ + C_4H_8 \longrightarrow ErC_4H_6^+ + H_2$$



quenching with Ar-Pulse

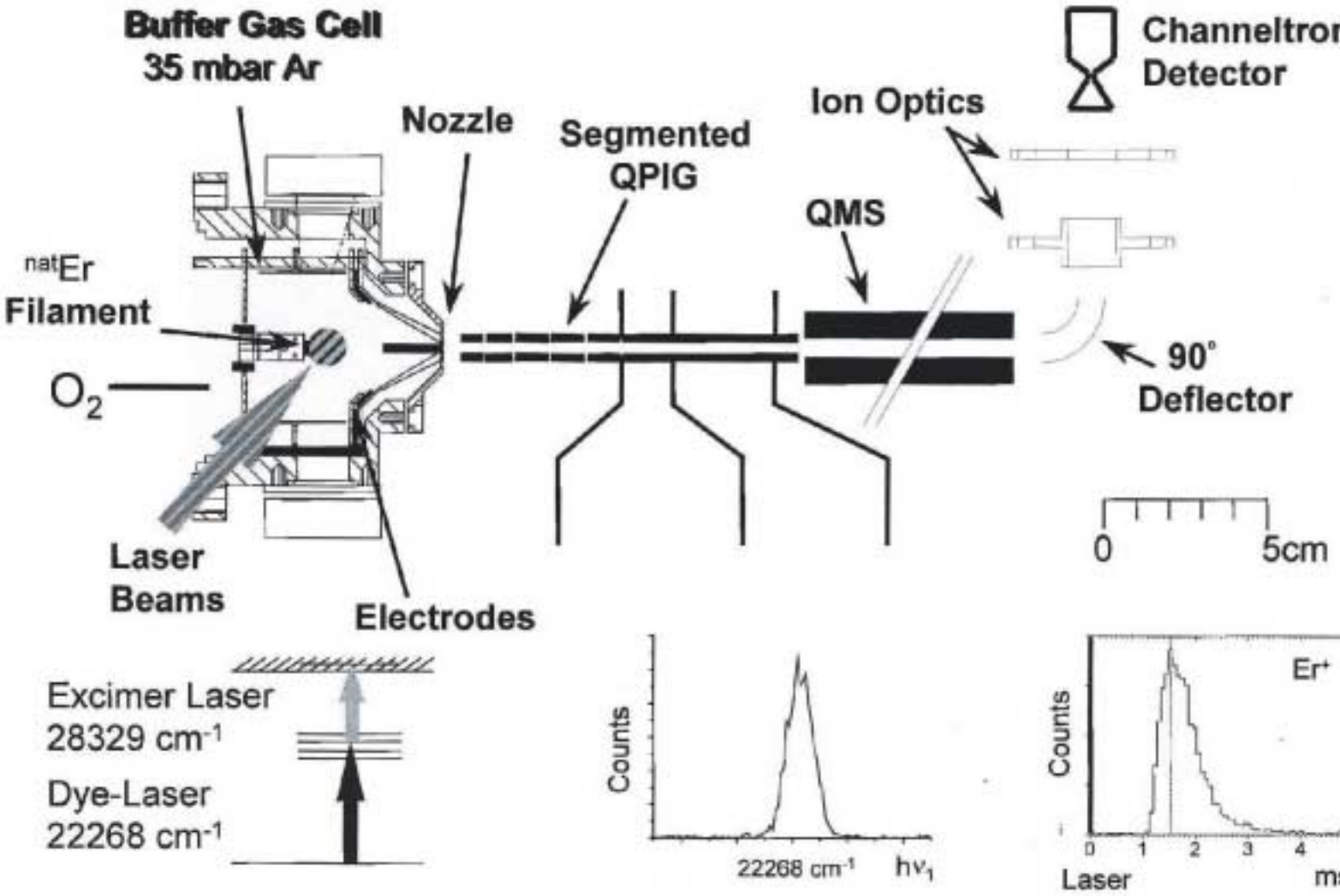
meta-stable ions
->
ground-state ions



k = (1.30 ± 0.14)·10^{-10} cm^3 molecule^{-1} s^{-1}

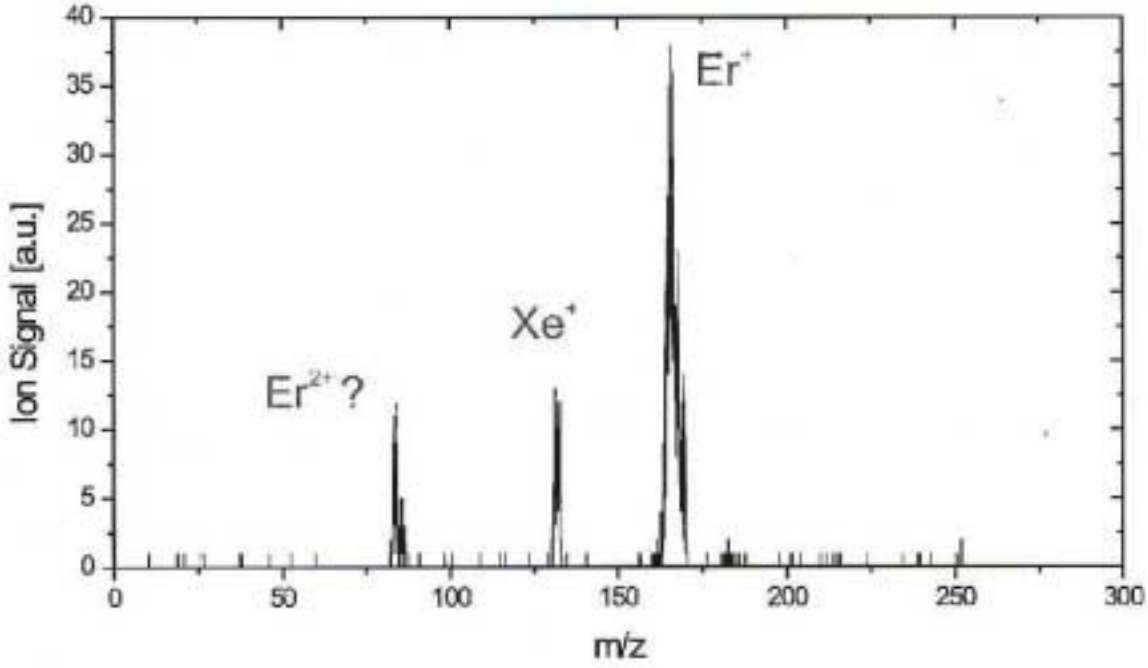
k = 0.13 k_{lv}

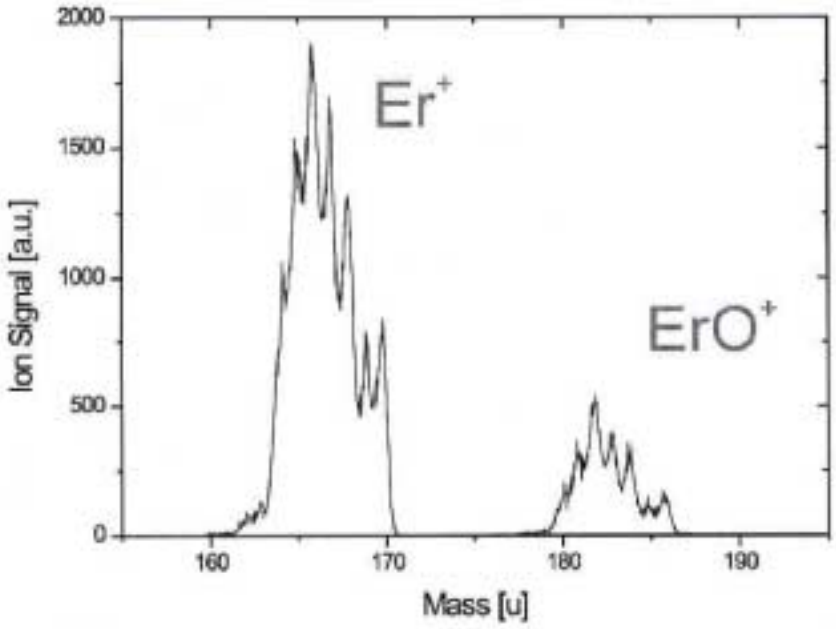
Ion Chemical Reactions Studies based on RIS

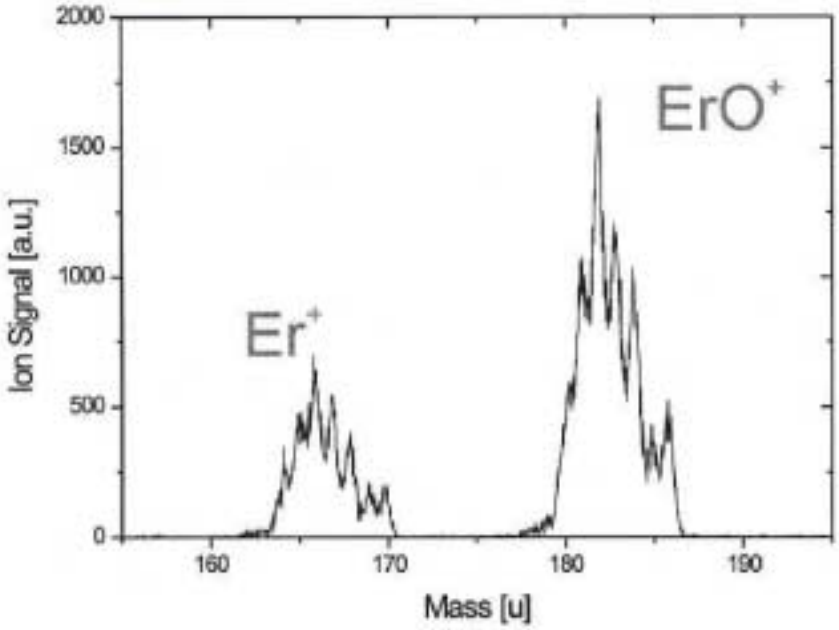


$Er^+ + O_2 \rightarrow ErO^+ + O$

Measured in the Buffer Gas Cell







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