# A 22-pole ion trap setup for astrophysically relevant reaction kinetic studies

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**Synopsis** Astronomical detection has identified the presence of complex molecules in extraterrestrial environments, yet their formation and evolution are poorly understood. Ion–molecule reactions are believed to play an important role in shaping their observed abundances. We have developed a 22-pole radio-frequency ion trap to investigate the kinetics of such reactions under controlled conditions. We present a systematic characterization of the setup and improvements to enable reliable determination of neutral-gas density and reproducible reaction rate coefficients.

Over the past several decades, more than 300 molecules have been detected in the interstellar medium. The formation mechanisms of these astromolecules remain an open question. The discrepancies between their predicted and observed abundances point to unknown mechanisms such as ion-molecule reactions that govern their evolution in astrophysical environments [1]. To study the kinetics of such cosmically relevant ion-molecule reactions under controlled laboratory conditions, we built a 22-pole radio frequency ion trap setup.

The experimental setup consists of an ion source, two quadrupole mass spectrometers, one 22-pole ion trap, and one channel electron multiplier detector, in the arrangement shown in Fig.1. A detailed description of all parts can be found in [2]. This apparatus can be used to measure reactions between cations and neutral molecules as a function of time, neutral gas density, and temperature. In addition, a laser beam horizontal to the spectrometer axis can be coupled with the ion trap to study the photon-induced ion-neutral reactions.

Here we discuss the results of all tests that have been done to investigate the influence of different experimental parameters and modifications to improve the ion trap setup. A major modification was carried out in order to measure the neutral density, which is essential for measuring reaction rate coefficients. For this, a capacitive gauge was directly connected to the trap volume. Furthermore, an experimental procedure will be described in order to get reliable and reproducible results for ion-molecule reaction rate coefficients. These developments provide a robust platform for quantitative studies of ion–molecule kinetics relevant to astrophysical environments.

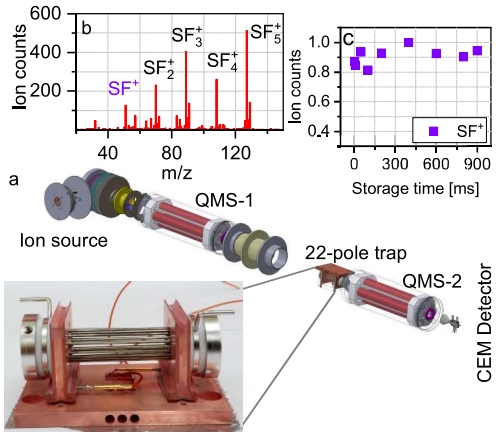


**Figure 1**. Schematic drawing of the modified 22-pole radio frequency ion trap setup (a). The ions are produced by a discharge or electron impact ion source and analyzed using first quadrupole mass spectrometer (QMS-1). A sample mass spectrum obtained upon discharge of $SF_6$ gas was shown here (b). Mass-selected $SF^+$ was injected into the ion trap and trapped for $\sim 1s$ (c). A second quadrupole mass spectrometer (QMS-2) was used for analysing the contents of the trap and detected using a channel electron multiplier (CEM) detector.

## References

[1] Siddhartha S P *et al.* 2026 *APJ* **1008** 212
[2] Nihar R B *et al.* 2024 *RSI* **95** 013201

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