Astrochemistry in ion traps: from cold hydrogen to hot carbon

Dieter Gerlich

Department of Physics, Technische Universität Chemnitz, Germany

Astrochemistry deals with the formation and destruction of matter in very different environments including the early universe, cold dense interstellar clouds, hot circumstellar regions, or planetary atmospheres. In this contribution I summarize our recent experimental activities in this field using radio frequency (rf) traps for confining ions and nanoparticles. Two electrode arrangements are shown in Figure 1. The cryogenic 22-pole is meanwhile a very common ion trap used for reaction dynamics and spectroscopy (see [1] and references therein), while the split ring electrode trap (SRET) has been developed for high temperature applications [2]. With closed cycle refrigerators, wall temperatures of 2.6 K have been achieved [3] while heating an C_{60}^+ ensemble with a CW CO_2 laser has resulted in temperatures above 2000 K [2].

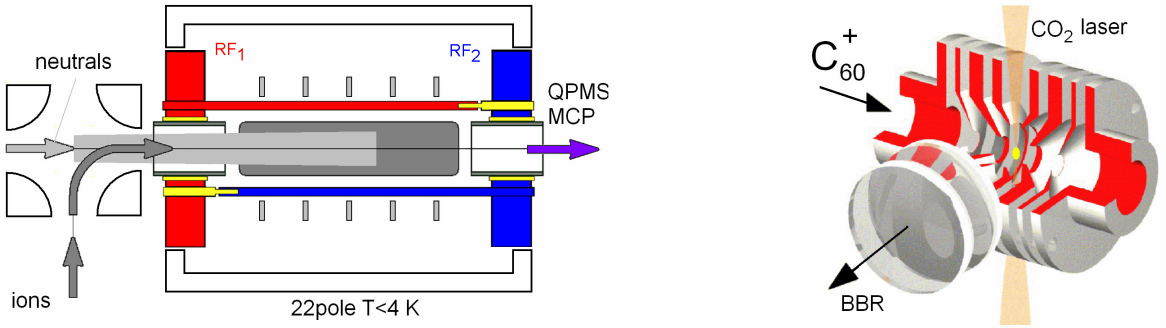

Figure 1: Left: 22pole ion trap for studying the interaction between cold stored ions and a beam of neutrals. Right: Special quadrupole trap for monitoring hot particles via their black body radiation (BBR).

Many gas phase processes involving ions have been studied in rf traps, including bi- and termolecular reactions, radiative association, clustering, isomerization, and isotope fractionation. In this talk, I will mention a few examples: (i) Associative detachment in $H^- + H$ collisions measured in the temperature range between 10 and 135 K. (ii) So far unexplained is the experimental result that $CH^+(v{=}0,J)$ does not react with H atoms for $J = 0$ at low temperatures, although the reaction is exothermic. (iii) In contrast to simple expectations, radiative association of H^+ colliding with $H_2(J)$ is a factor of 2 slower for $J = 0$ than for $J = 1$. (iv) For reactions of $N^+(^3P_{ja})$ with $H_2(J)$, first state specific rate coefficients $k(J, j_a)$ have been derived [1].

There are many innovative activities based on the combination of lasers and ion traps [4]. A powerful new instrument used a cryogenic wire quadrupole and tunable IR lasers [3]. Very versatile is the new spectroscopy method called Laser Induced Inhibition of Complex Growth (LIICG) which has been developed in Basel [5] for studying candidates for the diffuse interstellar bands (e.g. C_{60}^+). This method has been applied first to N_2^+ ions and extended in Köln to CH_5^+ and H_3^+. As an example for measuring the stability of objects in a high temperature stationary state, the decay rates of a cloud of C_{60}^+ ions also will be mentioned [2].

References

[1] I. Zymak, M. Hejduk, D. Mulin, R. Plašil, J. Glosík, D. Gerlich, 2013, Ap.J. **768,** 86.
[2] D. Gerlich, S. Decker, 2014, Appl. Phys. B, **114,** 257.
[3] J. Jašík, J. Žabka, J. Roithová, and D. Gerlich, 2013, Int. J. Mass Spectrom. **354-355,** 204.
[4] For more information and references see https://www.tu-chemnitz.de/physik/ION
[5] S. Chakrabarty, M.Holz, E.K. Campbell, A. Banerjee, D. Gerlich, and J. Maier, 2013, JPC Lett **4,** 4051.