New features in the thermionic emission from Al_n^- and SF_6^- ions

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We have investigated the thermionic emission of electrons from highly excited Al_n^-cluster ions (n=3…7) and SF_6^- molecular ions using the cryogenic trap for fast ion beams (CTF) at the Max-Planck-Institut für Kernphysik. Both measurements profited from the low collision background afforded by the trap's extreme high vacuum. Using an MCP mounted a short distance from the trap center inside the cryogenic vacuum system, we have increased detector acceptance compared to earlier experiments [1, 2], resulting in a much improved precision of our measurements.

In the case of SF_6^- there has been a long-standing controversy about its lifetime with regard to electron emission in case of production in excited states, which was resolved in a measurement [3] at ELISA. This measurement showed that the decay of the ion does not follow a simple exponential law, but a power law with an exponent near -1.5. We have now extended the dynamic range over which the thermionic emission rate following initial excitation was measured. While this dynamic range amounted to three orders of magnitude in [3], we have now reached almost 6 orders of magnitude by monitoring the rate of neutral particle production from a 6 keV beam of SF_6^- ions stored in the CTF with a collision-limited storage lifetime around 800 s at an average ambient temperature of 12 K. As one of the highlights of this experiment, a detailed investigation revealed that the exponent of the decay law can in fact be tuned between -1.0 and -1.5 by varying the operating parameters of the employed sputter ion source, which determine the initial vibrational excitation of the ions. Most notably we have also discovered a strong deviation from the power law after approx. 10 ms, which in [3] was obstructed by residual gas background. Although the subsequent steep decline of the emission rate can be reproduced by the radiative quenching model introduced to explain similar deviations found in the fragmentation of biomolecules [4], the associated time constant was found to depend on the ion source conditions as well, indicating a possible influence of the initial population of excited states.

We have further investigated the identical process for excited aluminum cluster ions (Al_n^-) with sizes from 3 to 7 atoms, stored in the CTF at an energy of 6 keV and at an ambient temperature near 12 K. While we had found a similar "rate quenching" behaviour as in SF_6^- in earlier investigations on Al_4^- and Al_5^- [2], we have now significantly improved the statistical quality of our measurements. This has led to the discovery of a previously unobserved contribution to the neutral particle rate in the quenching region, before the sharply declining count rate from thermionic emission merges with the background from residual gas collisions. The additional component, not accounted for in present emission models, was found to follow a power law with exponents between -0.4 and -1.5. It may hence point at an independent process that in previous measurements was not discernible from the residual gas induced background.

References

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