Beam Lifetimes and Cross Sections for 10-75 MeV/u U^{28+} and Xe^{18+} Ions*

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Several GSI future projects require intense beams of heavy ions, in particular uranium ions. To obtain the desired beam intensities and energy densities, space charge effects need to be minimized; this means using low-charge state ions, i.e., ions having charge states far below the equilibrium charge state. When these ions interact with background gases contained in the beamlines and storage rings, electron loss (stripping) occurs. This increases the mean charge state of the beam which decreases its energy density. It also reduces the overall beam intensity, limits storage lifetimes, and generates major detrimental effects such as wall erosion, excessive heat and vacuum loads, radiation buildup, etc. However, until recently, virtually no experimental data were available for low charged heavy ions. Therefore an experimental program accompanied by theoretical studies has been started recently in order to obtain a reliable basis for cross-section and luminosity estimates[1,2].

Our current work assesses the importance of electron stripping at MeV/u energies by measuring storage lifetimes for U^{28+} and Xe^{18+} ions within normal SIS and ESR vacuum environments. For modeling the interaction probabilities and storage lifetimes at higher energies or for other ions, lifetimes and cross sections for stripping by H_2 and N_2 were also measured. This was done using the ESR gas target.

Beam lifetimes were measured in the SIS and ESR for 10-75 MeV/u Xe^{18+} and 10-50 MeV/u U^{28+}. Lifetimes were measured for both cooled and uncooled beams. In addition, using cooled beams, lifetimes were measured at 50 MeV/u for Xe^{18+} - N_2 collisions and at all energies for U^{28+} - H_2 and N_2 collisions. For lifetimes resulting from interactions with hydrogen and nitrogen, ions were injected into the ESR, electron cooling was applied long enough to cool the beams, the electron cooler was turned off and a fast valve was opened to admit the supersonic jet from the ESR gas target. Preliminary measurements were performed to determine the best beam-jet overlap conditions. By monitoring the density of the injected molecular beams, the H_2 and N_2 lifetime data can be converted into absolute stripping cross sections.

Figure 1 shows our measured lifetimes for U^{28+} as a function of beam energy. The data are for interactions with H_2, N_2, and the "normal" background gases within the ESR. The ESR base vacuum was 2 x 10^{-11} mbar with the primary components being H_2 (87%), H_2O (5%), CH_4 (5%), CO_2 (2%) and Ar (1%).

Figure 1 shows that the uranium beam lifetimes due to interactions with N_2 are approximately a factor of ten smaller than for interactions with H_2, i.e., the cross sections for stripping by N_2 are approximately a factor of ten larger than for H_2. In addition, since the lifetimes are proportional to the cross section times the beam velocity, σv, the data show that above 20 MeV/u the stripping cross sections for interactions with N_2 have a v^{-1} dependence in the energy range investigated. In contrast, the stripping cross sections for interactions with H_2 have a faster, perhaps v^{-2}, dependence. The measured beam lifetimes in the ESR ring demonstrate a velocity dependence between these two values since they are determined by a weighted average of cross sections for the various gas constituents.

Most importantly, the data demonstrate that for base vacuum environments that can be achieved in storage rings, the lifetimes for these low-charge-state uranium ions are adequate (~50 seconds) for research associated with several future GSI projects.

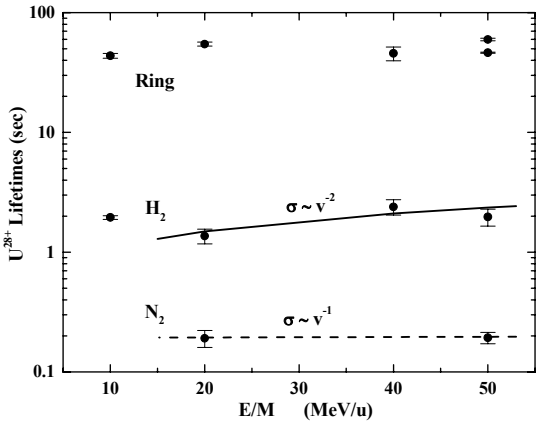

Figure 1: Preliminary lifetime data for beams of U^{28+} ions stored in the ESR ring. The data label "Ring" refer to lifetime data obtained without any additional internal target.

References

[1] R. D. DuBois et al., Phys. Rev. A **70**, 032712 (2004)
[2] R. E. Olson, R. L. Watson, V. Horvat, K. E. Zaharakis, R. D. DuBois, and Th. Stöhlker, NIM A 544, 331-336 (2005)

*Work supported in part by the Office of Fusion Energy Research, US Department of Energy