IONIZATION OF HYDROGENIC 33-TeV Pb IONS IN GAS TARGETS

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We measured the total cross section for ionization of Pb^{81+}(1s) ions in ultrarelativistic collisions (γ = 168). Because ionization is the limiting process for buildup of the Pb^{81+} fraction that occurs in the capture process, these results are important for understanding the equilibrium charge fraction of Pb^{81+} ions formed in a solid[1] or a gas[2] and in testing a new theoretical prediction of screening.[3]

The experiment at the CERN SPS used the apparatus discussed in our capture experiment.[1-2] The Pb^{81+}(1s) beam was formed upstream of the experiment via the capture process when the Pb^{82+} beam exiting the SPS traversed about 5 m of air and a thin beam line vacuum window (100 μm Al). The beam traveled ~300 m in vacuum (~10 mT) before passing through a gas cell outfitted with thin mylar windows. In the experiments, the entire evacuated beam line was tuned to transmit only the Pb^{81+} beam fraction. The coincidence signal from fast Cherenkov counters mounted at the end of the beam line monitored the fully transmitted Pb^{81+} beam. The ratio of signals, S(target in)/S(target out), was measured using several thicknesses of each target species (see Fig. 1). Exponential fits to this ratio yield the total ionization cross section, σ_i. Preliminary σ_i obtained for Ar, Kr, and Xe are 1.88, 6.8, and 15.5 kilobarns, respectively. These σ_i agree with experimental cross sections obtained from least square fits to capture growth curves using a 2-state model: 1.97, 7.38, and 15.7 kilobarns, respectively, from our independent capture measurements.[2]

The σ_i from both experiments are slightly lower than the recent estimates of Sørensen[3] but they agree within experimental and theoretical uncertainties: 2.11, 7.86, and 17.0 kilobarn, respectively. Sørensen has pointed out that the σ_i are roughly 1/2 of those obtained for 1s ionization using the method of Anholt and Becker[4] at γ = 168 because of a screening correction when γ is much larger than 10.

The σ_i measured in gas targets, scaled for target Z are substantially lower than those measured in solid targets. Ionization cross sections vary $\sim Z^2$ of the target and as $\sim n^2$ of the electron on the projectile. The gas-solid difference lies in the fate of excited states created either by collisional excitation or by capture into excited states. Electrons in excited states may be stabilized by radiative decay or removed by ionization in a second collision in the medium. At γ = 168, the normal radiative lifetime of Pb^{81+} (n = 2 $\rightarrow$ 1) (~4.6 x 10^{-17} sec) must be multiplied by γ and becomes 7.7 x 10^{-15} sec in the target frame. For gas targets, np states relax to the 1s state between collisions. In solids, where the mean free path is comparable to the radiative lifetime pathlength, excited states can be destroyed before they can relax. This leads to a substantial increase in the effective total ionization cross section observed in solids above Z = 13. The lower effective σ_i observed for gas targets (medium used to produce ions for this experiment) also increases the experimental equilibrium fraction, $f(81+) = \sigma_c/(\sigma_c + \sigma_i)$ relative to that observed in condensed high-Z targets.

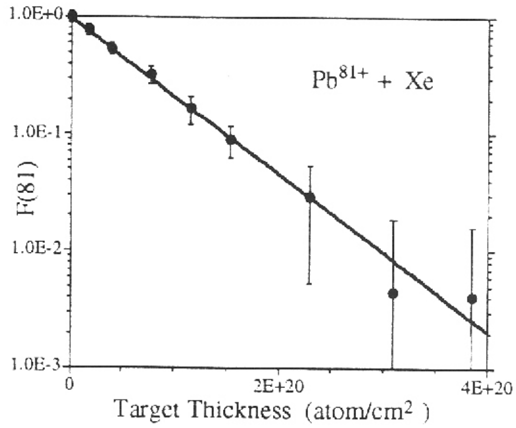

Fig. 1. Surviving fraction of Pb^{81+} ions versus Xe target thickness. The least squares fit to the data is shown.

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