ELECTRON CAPTURE FROM PAIR PRODUCTION BY 33-TeV Pb IONS IN GAS TARGETS

H. F. Krause,* C. R. Vane,* S. Datz,*

P. Grafström,[a] H. Knudsen,[b] U. Mikkelsen,[b] C. Scheidenberger,[c] R.H. Schuch,[d] and Z. Vilakazi[e]

*Physics Division, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee 3783-6377, USA

[a]CERN SPS/SL Division, CH-1211, Geneva 23, Switzerland

[b]Institute of Physics, Aarhus University, DK-8000, Aarhus C, Denmark

[c]Gesellschaft für Schwerionenforschung mbh, Planckstrasse 1, D-64291, Darmstadt, Germany

[d]Atomic Physics Department, Stockholm University, Frescativägen 24, S-104 05, Stockholm 50, Sweden

[e]University of Witwatersrand, Department of Physics, 1 Jan Smuts Avnue, P O Wits, Johannesburg 2050, South Africa

In ultrarelativistic heavy particle collisions such as Pb^{82+} on Xe ($Z_1\alpha = 0.59$) at 160 GeV/u, the predominant electron capture mechanism is from the e^+e^- pair produced when the projectile ion passes through the intense Coulomb field of a target atom at impact parameters greater than the internuclear radii. The capture cross section for this pair production mechanism ($Pb^{82+} + Xe \rightarrow Xe + Pb^{81+} + e^+$) predominates over other competing capture mechanisms such as radiative electron capture (REC) and nonradiative capture (NRC).[1]

Previously, we measured total capture cross sections for a variety of solid targets where ions formed in excited states are rapidly ionized inside the target.[2] Now we report capture cross sections measured in a gas cell where excited np states rapidly decay to the 1s state before the next collision.

In the experiment, $^{208}Pb^{82+}$ extracted from the CERN SPS were mass and charge state selected at the first bend of the beam line before impinging on a gas cell with thin mylar windows. The second bend of the 0.8 km beam line was set to transmit $^{208}Pb^{81+}$ ions leaving the cell The ion intensity at the end of the beam line was measured using the coincidence signal from fast scintillators when the full beam line was first tuned to pass Pb^{82+} (no target) and then when the second half was tuned to pass Pb^{81+} (target gas introduced). The ratio of normalized and corrected signals, S(81+)/S(82+), was measured using a number of target thicknesses each of Ar, Kr, and Xe. As an example, the growth curve of the fraction of Pb^{81+} ions, as a function of target thickness, is shown in Fig. 1 for Xe. These data were used to determine the total cross sections for capture (σ_c) and loss (σ_i) processes. Excellent fits to the data using a two-state model[2] were obtained for each gas, as indicated by the solid curve shown in the figure for Xe. Preliminary σ_C obtained for Ar, Kr, and Xe are 2.9, 10.1, and 20.7 barns; they are slightly above or equal to the σ_c expected for ions formed in the 1s state.[1-2] The corresponding σ_i obtained, 1.97, 7.4, and 15.7 kilo-barns, also agree with those obtained in a separate ionization experiment discussed in a companion abstract.[3]

The equilibrium fraction, $f(81+) = \sigma_c/(\sigma_c + \sigma_i)$, is 1.44×10^{-3}, 1.37×10^{-3}, and 1.32×10^{-3}, respectively, for these gases. These fractions are about 30% higher than those measured in solid targets of comparable Z.[2] The fraction of ions formed in excited states has been theoretically estimated to be in the range 20-30%.[1,4] Ions formed in np states have sufficient time to radiatively relax to the 1s state ($<10^{-14}$ in the target frame) between gas collisions but not in solids. Ionization cross sections vary $\sim Z^2$ of the target and as $\sim n^2$ of the electron on the projectile. Relaxation of excited states between collisions allows a higher fraction of the ions to survive after capture, lowers the effective ionization cross section and increases the equilibrium fraction, $\sigma_c/(\sigma_c + \sigma_i)$.

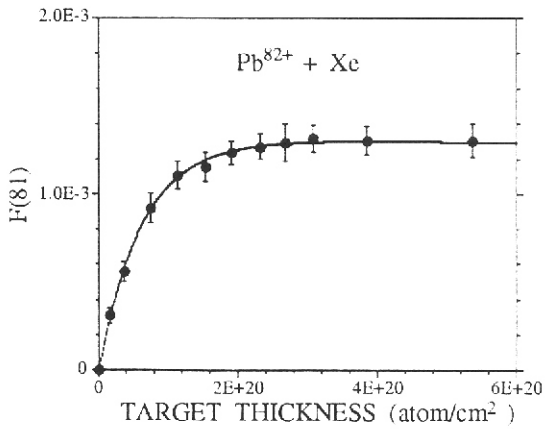

Fig. 1. Fraction of one-electron Pb^{81+} ions F(81) created by electron capture in Xe gas as a function of target thickness.

Authors (HFK, CRV, SD) acknowledge support by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Chemical Sciences under Contract No. DE-AC05-96OR22464 with Lockheed Martin Energy Research Corporation. HK acknowledges the support of the Danish Natural Science Research Council.

1. R. Anholt and U. Becker, *Phys. Rev. A* **36**, 4628 (1987).
2. H. F. Krause et al., *Phys. Rev. Lett.* **80**, 1190 (1998).
3. H. F. Krause et al., contributed paper in this proceedings.
4. C. K. Agger and A. H. Sørensen, *Phys. Rev. A* **55**, 404 (1997).