IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

CHARGE CHANGING CROSS SECTIONS FOR HEAVY IONS AT ENERGIES TO 8.5 MeV/AMU

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ABSTRACT

Preliminary cross sections for single electron pickup and loss are presented for Fe, Kr and Xe ions at 8.5 MeV/amu and for Ar ions at energies from 3.4 MeV/amu to 8.5 MeV/amu passing through nitrogen gas.

INTRODUCTION

In order to obtain beams of very high mass and energy, heavy ion accelerators must be capable of accelerating partially stripped heavy ions. A crucial factor in designing these accelerators is the vacuum required for beam survival; this depends upon the charge changing cross sections for collisions between beam ions and residual gas atoms. However, cross section data in the energy range of interest are largely nonexistent. To assist in determining the vacuum requirements for the Bevalac vacuum improvement project, we are measuring the cross sections of SuperHILAC-produced ions from neon (Z=10) to Xenon (Z=54) at energies from 3.4 MeV/amu to 8.5 MeV/amu (.085 ⩽ v/c ⩽ .134) in nitrogen gas over a wide range of incident charge states.

EXPERIMENT

This paper reports our first preliminary values for single electron capture and loss cross sections for ions of argon, iron, krypton and xenon at 8.5 MeV/amu and for argon ions at energies of 3.4 MeV/amu to 8.5 MeV/amu. A schematic diagram of the apparatus is shown in Fig. 1. Heavy ions obtained from the Lawrence Berkeley Laboratory SuperHILAC are stripped by a carbon foil and charge-state selected in the beam switch yard. Once collimated, they pass through a differentially pumped 24 cm long charge exchange chamber. The final states are analyzed in a homogeneous 18kG dipole magnet with an effective radius of 22 cm and detected on a position sensitive gas-filled proportional counter. At 8.5 MeV/amu each of the charge states of argon is separated by approximately 2 cm.

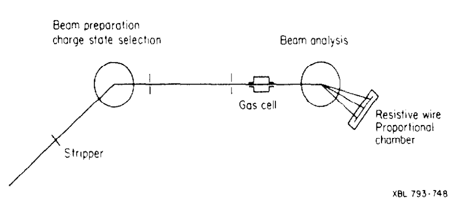

Fig. 1. Experimental layout at the SuperHILAC.

Ion charge states of atoms through Z=26 can be unambiguously identified by calibrating against fully stripped ions (bare nuclei) of the same atom produced by stripping in a solid foil. A narrow slit driven by a precision screw measures the absolute displacement of the beam for each charge state, permitting identification of heavier ions by matching the magnetic rigidity to lighter ions or by simple ray tracing calculations.

Data are collected by observing the relative number of ions striking the counter at each location corresponding to an ion charge state, as a function of gas pressure in the charge exchange cell. The ratio of peak heights to background is about 50:1. The largest sources of error are due to uncertainties in the column densities of the gas in the charge exchange chamber, charge exchange due to slit scattering, and double electron capture and loss which is not as yet included in our data analysis. We estimate these uncertainties to be 20%. To test for gross errors we remeasured single electron pickup cross sections for Fe^{25+} and Fe^{26+} in argon gas (first measured by Berkner et al[1]). Our values of 5.0×10^{-18} and 5.5×10^{-18} cm^2/atom for Fe^{25+} and Fe^{26+} respectively agree well with Berkner's values of 5.6 and 5.8×10^{-18} cm^2/atom.

DATA

Figures 2 and 3 and Table 1 show the measured velocity dependence of the charge capture and loss cross sections in N_2 of argon ions with five or fewer electrons, and Table 2 lists the measured cross sections for highly stripped Fe, Kr, and Xe ions at 8.5 MeV/amu in N_2. A more extensive data analysis and measurements of charge changing cross sections for heavier ions is in progress.

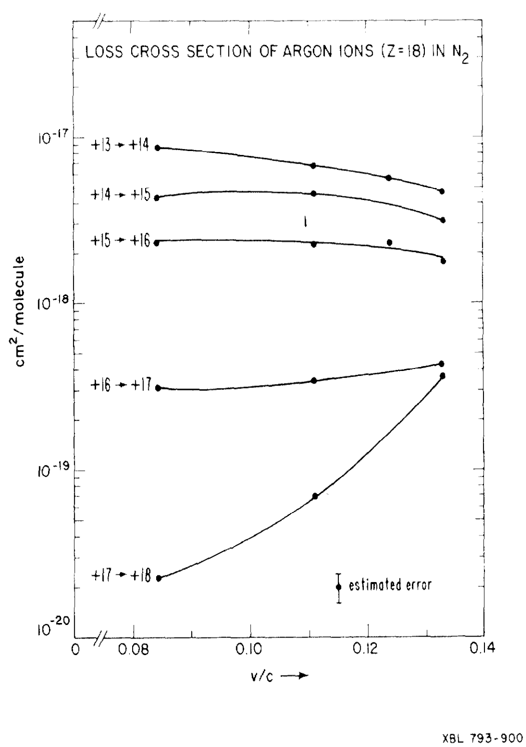

Fig. 2. Single electron loss cross sections as a function of ion velocity for argon ions in nitrogen gas.

*Work supported by Division of Chemical Sciences and Division of High Energy and Nuclear Physics.

0018-9499/79/0600-3686$00.75 © 1979 IEEE

Table 1. Argon charge changing cross sections in N_2

Velocity (v/c)	Ion	Capture	Loss
	Cross Sections in Units of 10^{-19} cm^2/molecule		
.1342 (8.5 MeV/amu)	+18	10.3	--
	+17	8.0	3.7
	+16	5.4	4.3
	+15	4.8	18
	+14	2.3	31
	+13	--	52
.1236 (7.1 MeV/amu)	+15	11	23
	+13	4.6	57
.1113 (5.8 MeV/amu)	+18	48	--
	+17	33	.69
	+16	30	3.4
	+15	16	21.7
	+14	15	45.7
	+13	8	66.3
.0846 (3.35 MeV/amu)	+18	170	--
	+17	140	.23
	+16	150	3.1
	+15	116	23.
	+14	63	43
	+13	53	86

ACKNOWLEDGMENTS

We wish to acknowledge the assistance of Jeanette Mahoney in the assembly and testing of the detector, and Rich Leres for providing the data acquisition software.

REFERENCES

[1] K.H. Berkner, W.G. Graham, R.V. Pyle, A.S. Schlachter and J.W. Stearns, LBL-5991 (1977); also, Proceedings of 10th Int. Conf. on Phys. of Electr. and At. Coll., Paris, July 1977, p. 542.

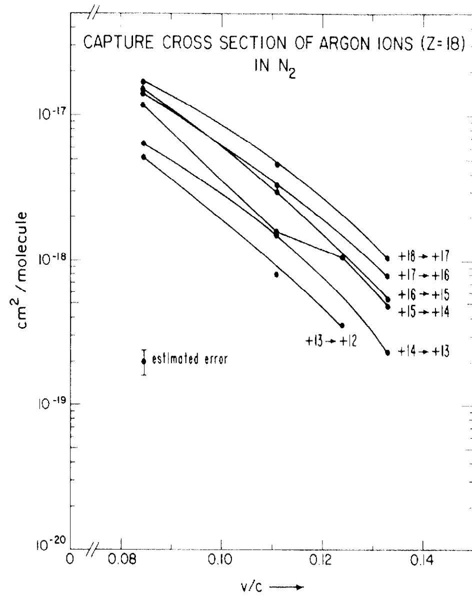

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Fig. 3. Single electron pickup cross sections as a function of ion velocity for argon ions in nitrogen gas.

Table 2. Charge Changing Cross Sections in N_2 at 8.5 MeV/amu

Atom	Ion	Capture	Loss
	Cross Sections in Units of 10^{-19} cm^2/molecule		
Fe (Z=26)	+26	34.3	--
	+25	27.4	3.2
	+23	22.9	8.0
	+20	11.4	41
	+17	9.1	82
Kr (Z=36)	+33	66	2.3
	+27	21.7	18.3
	+21	4.5	94
Xe (Z=54)	+46	120	3.3
	+41	77	16
	+34	36.5	53
	+28	--	177