Systematics of the Energy Dependence of Projectile Charge-changing Cross Sections

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Cross sections for single electron capture as well as single and multiple electron loss of Xe^{18+} projectiles in single collisions with N_2 molecules were measured as a function of the beam energy [1]. The objective of this report is to examine the systematics of the results and to provide the means for making reliable estimates of other cross sections that were not directly measured.

It was found that the logarithms of cross sections $\sigma_{\Delta q}(E)$ for single and multiple electron loss as a function of beam energy E can be reasonably well represented with straight lines, i.e.,

$$\log\sigma_{\Delta q}(E) = c_o(\Delta q) + c_1(\Delta q)\, E, \qquad (1)$$

where E is in MeV/u and σ is in Mb per atom. The intercept c_o and the slope c_1 of these lines are found to be smooth functions of Δq, the number of electrons stripped from the projectile. Specifically, the intercepts c_o were represented by a third-order polynomial in Δq, i.e.,

$$c_o(\Delta q) = b_o - b_1\Delta q + b_2(\Delta q)^2 - b_3(\Delta q)^3, \qquad (2)$$

while the slopes were represented by the sum of a constant and a Gaussian function of Δq, i.e.

$$c_1(\Delta q) = -a_o + a_1\exp[-0.5(\Delta q - a_2)^2/a_3^2]. \qquad (3)$$

Initially, the parameters a_o, a_1, a_2, a_3, b_0, b_1, b_2, and b_3 were determined simultaneously in a least squares fitting procedure using all available experimental data. However, in this process it was found that the best-fit value of $c_1(2)$ differed significantly from the value obtained from the fit of the double loss cross section data alone using eq. (1) and varying $c_o(2)$ and $c_1(2)$ as independent parameters. Therefore, the measured double-electron loss cross sections were excluded from the data set and the best-fit values of the parameters a_o, a_1, a_2, a_3, b_0, b_1, b_2, and b_3 were re-evaluated. The results are shown in Table I.

Table I: Best-fit values of the parameters a_o, a_1, a_2, and a_3 from eq. (3) and b_0, b_1, b_2, and b_3 from eq. (2) based on the simultaneous fit to the complete set of measured electron loss cross sections, excluding those related to double-electron loss.

Par.	Value	Par.	Value
a_o	1.07677E-01	b_o	1.90742E+00
a_1	7.61435E-02	b_1	6.90499E-01
a_2	1.78906E+00	b_2	1.23032E-01
a_3	2.83733E+00	b_3	8.96020E-03

The best-fit values of $c_o(2)$ and $c_1(2)$ obtained from an independent fit of the double-electron capture cross sections were found to be 0.884187 and $-8.20030\cdot10^{-3}$, respectively. The reason for this non-systematic behavior of $c_1(2)$ is yet unclear. The measured total projectile stripping cross sections were analyzed in the same way. The results are: c_o(total) = 1.63121, c_1(total) = -0.0330888. Logarithms of the cross sections for single-electron capture by the projectile were fitted by a quadratic function of E, i.e.,

$$\log\sigma_c(E) = d_o + d_1\, E + d_2\, E^2. \qquad (4)$$

The best-fit values of the parameters of eq. (4) were found to be d_o = 1.65999, d_1 = -0.457390, and d_2 = 0.0180006. The measured cross sections and the best-fit functions are shown in Fig. 1. The quality of the fits is good, considering the number of data points and the overall number of fitting parameters.