FRACTION AND QUENCHING CROSS-SECTION MEASUREMENTS OF MULTIPLY-CHARGED METASTABLE IONS BY A ONE-SHOT GAS PUFF METHOD

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This paper discusses the electron transfer or charge exchange cross-sections of multiply-charged ground-state (GS) ions and the cooling or quenching cross-sections of multiply-charged metastable-state (MS) ions due to a multiply-charged ion (MCI)-atom collision interaction. Also discussed is the fraction of MS ions in the beam under use. In order to measure the above quantities reliably and systematically we propose a single-pulse compressed gas injection method which has advantages over more conventional methods:

- the method does not disturb the MCI source;
- data can be taken in the matter of 100 ms per shot; and
- the amount of target gas injected is quite little per shot.

The JPL MCI Facility has currently four beam lines dedicated to measure properties of MCIs of astrophysical interest: Beam line A) Electron impact collision cross-sections, B) Forbidden line oscillator strength, C) Charge exchange cross-section, and D) X-ray photon emission. Beam lines A and B determine absolute values essential to spectroscopic study of the space and planetary plasmas. Beam lines B and C also concern the absolute cross-sections of respective process in order to confirm models of the solar wind-cometary gas interaction.

For all the beam lines knowledge of the fraction, f, of the MS ions is of crucial importance. In B the MS ion itself is the target, and enhancement of its f is our present research subject. In A and C, however, the MS ions are an impurity, passed by the dipole-magnet mass to charge-state analyzer because of their identical m/q with ground-state (GS) ions. Our current interest is in measurements of only the GS transitions in A, and only the GS capture of one or more electrons in C.

Let us define the f explicitly as the fraction of the MS ion current (I_{MS}) to the total ion current ($I_t = I_{GS} + I_{MS}$). Then GS-current is given by $I_{GS} = (1-f)I_t$ where $f \equiv I_{MS}/I_t$. This I_{GS}, rather than I_t, must be used for the excitation and charge exchange cross-section calculations in order to eliminate the MS transition and MS electron capture contributions, respectively. Neglecting f may cause a 100% of error in the excitation cross section if f=0.5, since $\sigma_{ex} \propto (1-f)^{-1}$. It is less serious for the case of charge exchange cross sections since $\sigma_{cex} \propto -\ln(1-f_{q-1})/(1-f_q)$, where f_{q-1} and f_q are the MS fractions in the beam of charge states q-1 and q, respectively.

It is understandable that MS ions are produced in MCI sources such as ECR ion source (ECRIS) in which electrons with $T_e \leq$ 500eV are interacting with the well-trapped MCIs for a quite sometime (~40 ms). Not only the step-ionization process but also the electron-capture process from the low-q ions and from the surface of the beam extraction optics may populate the forbidden levels if the decay is selective to that state. We are investigating if f increases with q, since the electron-capture cross-section increases with q. If the decay is not state selective[1], the electron-captures must trigger a Lyman decay for all levels including forbidden levels.

The attenuation experiment was carried out with a newly implemented piezo-electric valve controlled by a 100 V, ~80 ms square pulse generator. Various target gases were injected into the beamline immediately after the dipole magnet. The ion beam current (I_t) decays as the injected gas pressure (p) increases up to 100 μTorr within 100 ms. The p(t) and $I_t(t)$ data were captured on a digital scope before disturbance of the ECRIS, and within a 150 ms window after the gas injection. The initial current decay is due to the MS ions, because their electron capture cross section is larger than that of GS ions. **Figure 1** shows raw data and the analysis procedure. An exponential fit is made (Step 1) to obtain the expression I_{GS}=550exp(-0.039p), which is subtracted (Step 2 in insert) from I_t and another fitting on them obtains I_{MS}= 51.0 exp(-0.105p). Thus we find $f \equiv (I_{MS}/I_t)_{p=0} = 51/(550+51) = 8.5\%$ for O^{2+} (it was f=25% for Fe^{9+}). Since p(N/m^2)=2.83x10^{-17} n_o(m^{-3}), the I_{GS} charge exchange and I_{MS} quenching cross sections are found to be 1.90x10^{-14} and 5.12x10^{-14} cm^2, when the interaction length L=0.58 m, respectively.

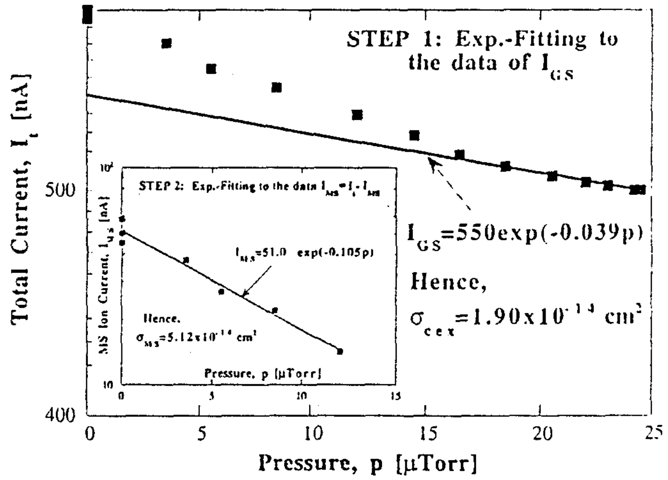

Figure 1. Stern-Volmer[2] plot of O^{2+} in Ar at 0.87keV/amu.

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