Studies of Autoionizing States Relevant to
Dielectronic Recombination

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Progress Report

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I. Introduction

In the past year we have focused most of our effort on the study of the 3pnl autoionizing states of Mg. Specifically, we have measured the angular distributions of electrons ejected from these states, we have carried out theoretical analyses of the experimentally determined angular distributions, and we have also made measurements of the autoionization rates of Mg 3pnk Stark states in electric fields. Finally, we have recorded the spectra of the autoionizing Ba 6pnk Stark states with very high optical powers to see the fine details in the wings of the spectra. Each of these activities is described in more detail in the ensuing paragraphs.

II. Progress

During the past year we have analyzed the angular distributions of the electrons from the Mg 3pns states. The measurements had been done in the prior year. The analysis was done using the K matrices calculated by Greene, which we had already compared to the total photoabsorption cross sectios of the Mg 3pns and 3pnd J=1 and J=3 states.[1,2] While the K matrix gave an excellent representation of the photoabsorption cross section, it was not clear that it would do as well for the angular distributions, for they provide a much more stringent test. However, the agreement between the experimental observations and the K matrix calculations is excellent. The

only discrepancy is that the experimental data exhibit a more pronounced dip in the parameter between the locations of the Mg^{+} ion lines than does the calculated ß parameter.[3]

During the past year we have carried out the measurements of the angular distributions obtained when exciting the 3pnd states from the bound 3snd states. The 3snd states are excited by two lasers linearly polarized in the same direction and are thus aligned. More specifically, they are in the m=0 state. The third laser, which excites these states to the 3pnd states is also polarized in the same direction, so that the final states which can be produced are those in which J=1 or 3 and m=0. Polarizing all three lasers in the same direction ensures that only J=1 and 3 final states are present. Any other choice of polarization would allow the excitation of J=2 states as well.

We measured both the total ion production and the number of electrons ejected at the angle θ relative to the polarization of the laser as we scanned the wavelength of the laser. This proceedure was repeated for ten values of the angle θ to obtain the coefficients of the angular distributions. We fit the data to the form

$$I(\theta) = 1 + \beta P_2 \cos(\theta) + \gamma P_4 (\cos(\theta) + e P_6 \cos(\theta)$$

In essence, we have measured the parameters ß, γ, and ϵ. .
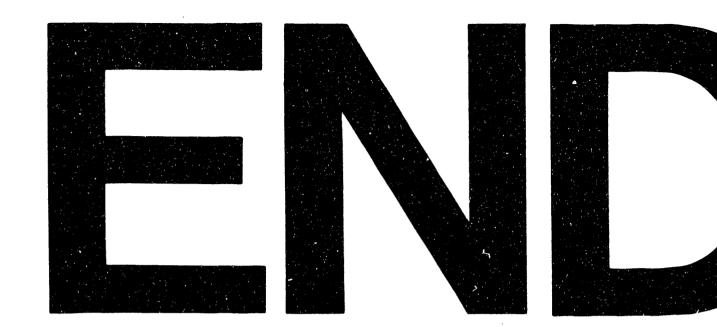We have used the same K matrices provided by Greeene to

calculate the total J=1 and J=3 absorption to calculate the angular distributions. In addition, Robicheaux and Greene have calculated the angular distributions using an expanded K matrix and a different form of the theory. Both calculations give results which are in excellent agreement with the experimental results.

In the past we have studied the autoionizing Ba 6pnk Stark states, and we have found that from a single bound 6snk Stark state that we excite a single 6pnk Stark stste.[4] The widths of the lines could be fit easily to Lorentzians and the dependence was easily explained using a hydrogenic description of the Stark effect. The previous measurements did not address the question of what the channels are in the presence of an electric field. During the past year we have examined the wings of the 6snk-6pnk transitions, using high optical powers, to address this question. We have observed clear structure in the wings due to the other Stark states. Typically, they produce a modulation of 15% of the total intensity. While we can easily identify the probable source of the modulation, we have not yet succeeded in carrying through a complete analysis. An extension of the quantum defect theory of the Stark effect, as worked out by Harmin or Sakimoto,[5,6] is required.

Finally, we have observed the Mg 3snk-3pnk transitions in electric fields. The results are not at all what we expected to see. Only in rare cases does the spectrum reduce to one line as

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it does in Ba. Usually there are half a dozen strong lines. Why Mg is so different is not immediately clear, but we suspect that the difference stems from the fact that in Mg the fine structure splitting of the 3p state of the ion is only 92 cm^{-1}, so that the Stark states of n= 10 to 20 are mixtures of states converging to both limits, with the result that the bound and autoionizing Stark states are not the same. We plan to use a microwave field as well, to mimic the effect of the time varying microfields in a plasma, to see if the results in that case are also different from the Ba results.

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