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PRODUCING A STEADY-STATE POPULATION INVERSION*

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MASTER

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ABSTRACT

An observed steady-state transition at 17.5 nm is identified as the $2p^53s3p\ ^4S_{3/2} \rightarrow 2p^63p\ ^2P_{3/2}$ transition in Na-like aluminum. The upper level is populated by electron inner shell ionization of metastable Mg-like aluminum. From the emission intensity, the rate coefficient for populating the upper level is calculated to be approximately 5×10^{-10} cm^3/sec. Since the upper level is quasi-metastable with a lifetime 22 times longer than the lower level, it may be possible to produce a population inversion if a competing process to populate the lower level can be reduced.

INTRODUCTION

Quasi-metastable levels of Na-like ions and atoms have previously been proposed as appropriate upper levels in producing population inversions.[1] In this previous study, the inversion between the $2p^53s3p\ ^4S_{3/2}$ upper level and the $2p^63p\ ^2P_{3/2}$ lower level in Na and Mg^+ was investigated. In this paper, an investigation of this same transition in Al^{2+} is presented. Also included is a technique for populating the upper level, an observation of the transition, and an experimental estimate of the population rate.

INNER SHELL IONIZATION

The inner shell (2p) ionization rate of Al^+ for energies well above threshold (100 eV) may exceed the outer shell ionization rate.[2] For Al^+ in the metastable states ($2p^63s3p\ ^3P_{0,1,2}$), the 2p ionization will populate the $2p^53s3p$ levels in Al^{2+}. Using a multiconfigurational code to calculate the autoionizing and radiative decay rates and assuming a 2J+1 weighting factor in populating the upper levels, a radiative emission spectrum can be predicted. Figure 1 shows such a spectrum which includes a 0.05 nm broadening and a 1% increase in the predicted energy levels to slightly decrease the wavelength of the lines, which improves the fit to the data and is well within the uncertainty of the calculation.

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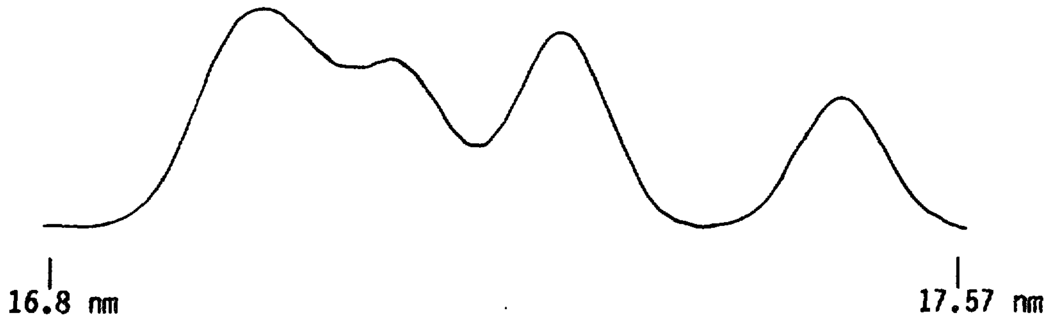

Fig. 1. Predicted spectrum of the $2p^53s3p$ - $2p^63p$ transitions.

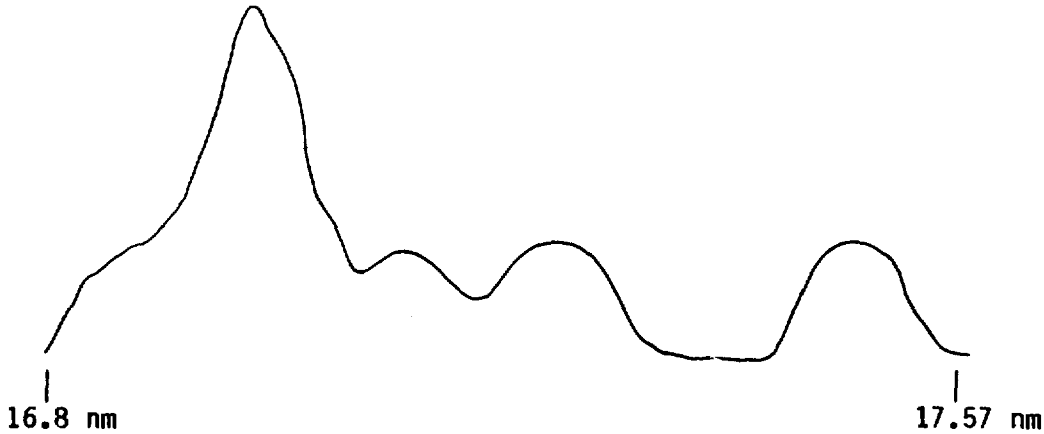

Fig. 2. Observed spectrum between 16.8 and 17.0 nm.

An experimental observation of these transitions is shown in Fig. 2. This was taken with a scanning 2.2 m monochromator observing radiation from the ELMO Bumpy Torus experiment.[3] This device produces a steady-state plasma with aluminum as the dominant impurity and has an electron temperature typically 300 eV. These same transitions have been observed in emissions from Penning discharges.[4,5]

Because the $^4S_{3/2}$ level has the lowest energy of the $2p^53s3p$ levels the $2p^53s3p\ ^4S_{3/2} \rightarrow 2p^63p\ ^2P_{3/2}$ transition will occur at the longest wavelength, in Fig. 2 this is at 17.5 nm. The intensity of this transition may be used to estimate the population rate coefficient by comparison to another intensity with a known excitation rate. Since the 16 nm pair is produced by inner shell ionization of Al^{2+} in this plasma[3] with a rate coefficient approximately 5×10^{-9} cm^3/sec[6], the density ratio of Al^{2+} to metastable Al^+ is typically 3, and the intensity ratio of the 17.5 nm line to the 16 nm pair is approximately 0.03; then the rate coefficient for populating the $2p^53s3p\ ^4S_{3/2}$ level will be 5×10^{-10} cm^3/sec.

THE POPULATION INVERSION

The lifetime of the $2p^53s3p\ ^4S_{3/2}$ state is 39 nsec which is 22 times longer than the $2p^63p\ ^2P_{3/2}$ state. This large difference will permit a steady-state population inversion to be maintained. The major problem in keeping the inversion comes from the ground state population in Al^{2+}. Because of the large electron collisional excitation rate from the ground state to the $2p^63p\ ^2P_{3/2}$ level, the ground state density must be kept well below that of the metastable Al^{1+} density.

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