Comments and Addenda

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Two-step photoionization of potassium atoms

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The cross section for photoionization of potassium atoms in the $4\,^2P$ states has been measured in a triple-crossed-beam experiment.

Two-step photoionization of alkali atoms via an intermediate excited state constitutes a new and extremely sensitive method for detection of very low alkali number densities. Theoretically, single atoms may be identified and detected using this method.[1] Our previous contribution to this field has been to measure the cross section for photoionization of cesium atoms in the $6\,^2P_{3/2}$ and $6\,^2P_{1/2}$ states as a function of wavelength.[2]

The purpose of this Comment is to report on new data obtained in potassium. The experimental technique has been discussed previously[2] and will only be described briefly here: A potassium atomic beam of density 10^{10} cm^{-3} is produced in a two-stage oven. The output stage is at a temperature of 150 °C higher than that of the reservoir in order to decrease the K_2 dimer concentration in the beam. Potassium atoms in the $4\,^2P_{3/2,1/2}$ states were produced by an Osram lamp,[3] resulting in an estimated excited-state density of about 10^5 cm^{-3}. The excitation radiation (7665 and 7699 Å) was chopped in order to discriminate against photoionization of potassium dimers as well as additional background effects, as discussed in our original paper. The ionizing radiation was produced by a mercury-xenon lamp[4] in conjunction with a $\frac{1}{4}$-m monochromator.

Digital synchronous detection[5] was used to discriminate against background effects. During the time interval when the chopper controlling the excitation radiation is open, we count "signal plus noise," including photoionization of ground-state atoms which may occur for $\lambda < 2844$ Å. On the other hand, when the chopper is closed, photoionization of excited atoms does not take place. The difference between the two count rates gives the count rate due to photoionization of excited atoms. The resulting net ion count rate was of the order of 0.1 to 5 sec^{-1}. Data accumulation times of 3–10 h were required to reduce the random statistical error to 20%.

The results are shown in Fig. 1. Each experimental point represents an average of four to five individual measurements; the error bars indicate the maximum spread in the data. To our knowledge, no other measurements have been made of cross section for photoionization of the $4\,^2P$ states in po-

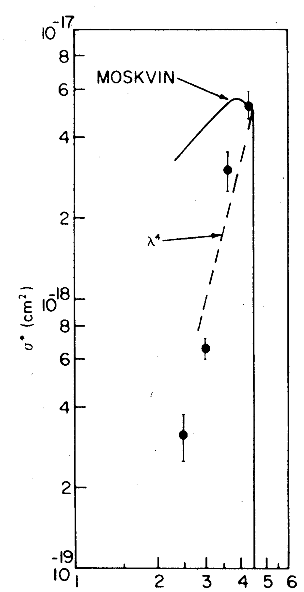

FIG. 1. Photoionization cross section of $4\,^2P$ potassium atoms normalized to the quantum-defect calculation of Moskvin (Ref. 10) at 4358 Å.

tassium. We did not attempt to resolve the $J=\frac{1}{2}$ and $\frac{3}{2}$ states for the reason that they are expected to have a similar wavelength behavior as do the previously studied $6P$ states in cesium.[6] As an important consistency check we made repeated measurements at the strong mercury line at 5460 Å and did not find any net ion count rate. The difference detection scheme is thus capable of discriminating against surface background effects at this wavelength. We also checked that the net ion count rate was proportional to the potassium density in the neutral beam (measured with a hot tungsten wire surface ionization detector[7]) and proportional to the intensities of the exciting and ionizing light beams.

Theoretically, little work has been done on photoionization of excited states in the alkali atoms. Weisheit[6] and Norcross[8] did model potential calculations in cesium and Caves and Dalgarno[9] made similar calculations in lithium. The only available results in potassium are the quantum-defect calculations of Moskvin,[10] shown as a full-drawn line in Fig. 1. We note that the experiment indicates a much stronger wavelength dependence than that predicted by the quantum-defect model. One would expect a hydrogenic cross section to behave as λ^3 at threshold. For comparison we have indicated a cross section proportional to λ^4. This approximate behavior was found previously by Mohler and Boeckner[11] in photoionization of the $6P$ states in cesium.

In view of the current interest of excited and highly excited states in the alkalies, more studies, theoretical and experimental, are needed.

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[3]Potassium spectral lamp from the Edmund Scientific Company.

[4]250-W high-pressure Hg-Xe lamp and housing from Ushio Electronics, Tokyo, Japan.

[5]SSR Model 1110 digital synchronous computer, PAR.

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[8]D. W. Norcross (private communication). His results agree closely with those of Weisheit (Ref. 6).

[9]T. C. Caves and A. Dalgarno, J. Quant. Spectrosc. Radiat. Transfer 12, 1539 (1972).

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