Resonances in the cross section of excitation of a potassium ion by electronic collision

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The excitation of an ion of one of the alkali elements—potassium—by electronic collision is investigated for the first time. Three sharp peaks were observed in the energy dependence of the radiation yield of the resonance levels of K^+. These peaks are attributed to the capture of the incident electron by the autoionizing levels of the neutral atom whose decay increases sharply the population of the lower excited states of the ion.

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Investigation of the inelastic processes produced as a result of interaction of ions (including metallic elements) with electrons is of particular interest in atomic physics, plasma physics, and applied physics. A number of papers devoted to the study of ionization and excitation of ions by electronic collision have been published (see Ref. 1). In particular, the excitation process of lower levels of alkali-earth metal ions has been comprehensively studied.[2,3] However, the excitation of alkali ions by electronic collision to date has not been studied theoretically or experimentally because of the relatively small excitation cross sections of these elements and because the emission of the resonance lines of these ions is in the vacuum ultraviolet region.

The experiments performed in our laboratory in recent years have paved the way for such investigations. In this paper, we report the first results of an investigation of the electronic excitation of the resonance levels of an ion of one of the alkali elements–potassium–by recording the emission with $\lambda = 60.1$, 60.8, and 61.3 nm.

An experimental setup with intersecting electron and ion beams, which is basically the same as that described in Ref. 3, was built for this purpose. One of its principal improvements, is the replacement of the commercial-type monochromator for the visible region of the spectrum by a special vacuum monochromator with an appropriate system of recording the useful signal (for description of equipment used, see Ref. 4).

The plot of the energy dependence of the yield of the total resonance radiation corresponding to the transitions from the $4s[3/2]^0$, $3d\,[1/2]^0$, $4s'[1/2]^0$ levels of the K^+ ion to its ground state $3p^6\ {}^1S_0$ is shown in Fig. 1. Note that in these experiments the

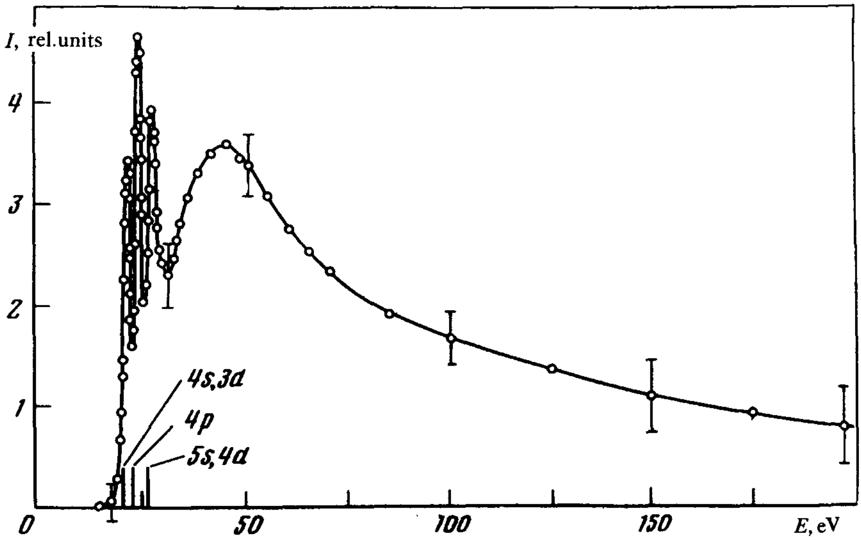

FIG. 1. Excitation function of the resonance radiation of the K^+ ion.

useful signal-to-background ratio varied from 1/6 (in the near-threshold energy region of the electrons) to 1/50 (for the electron energies 150–200 eV). Therefore, we were able to detect vacuum UV radiation only when the electron and ion beams were modulated simultaneously. To obtain satisfactory statistics, we conducted one measurement for 300 to 500 s and obtained approximately 20 data points during the 10 to 15 h measurement cycle. Therefore, the set of approximately 60 points on the curve represents a series of experiments; moreover, each experimental point in Fig. 1 was obtained by averaging 5 to 10 individual measurements. To obtain reliable results, we either reproduced the parameters of the experiment for each measurement or corrected for the variation in the beam current, the exposure time, etc. The energy scale was calibrated with an accuracy of ± 0.5 eV. The mean-square measurement error is represented by the vertical lines.

As seen in Fig. 1, the obtained excitation function has three sharp peaks just beyond the excitation threshold of the resonance levels of the potassium ion in addition to the broad peak in the 40 eV region and a smooth decrease to 200 eV just beyond it. These peaks, whose width depends on the degree of energy homogeneity of the electron beam, become narrower with increasing energy homogeneity. The width of the first peak coincides with the energy inhomogeneity of the electron beam.

As follows from Fig. 2, the location of these peaks corresponds to the excitation energy of the 4*s* and 3*d* resonance levels and of the two narrow groups of the higher-lying 4*p* levels and 5*s* and 4*d* levels. This indicates that the second and third peaks are caused by the cascade population of the resonance levels of the potassium ion. However, such resonance energy dependence of the cross section for excitation of the nonresonce levels of the ion by electronic collision has not been observed earlier.[1] This, in turn, suggests that the sharp peaks are not produced as a result of a direct excitation of the energy levels of a potassium ion due to the electronic collision but rather as a result of the capture of an electron by an ion, which produces autoionizing atomic states whose decay (due to the Koster-Kronig effect) produces the usual ionic states

$$K^+(3p^6) + e \to K^{**}(3p^5 n'l'n''l'') \to K^{+*}(3p^5 nl) + \tilde{e},$$

where $\tilde{e}$ is the emitted electron. In the light of this reaction, the mechanism for production of the three sharp peaks on the excitation curve is as follows. The first peak is produced because of the autoionizing states of the atom (see Fig. 2), which are adjacent to the resonance levels of the ion, and the second and third peaks are produced because of the corresponding autoionizing states, which are adjacent to the higher-lying 4*p*, 5*s*, and 4*d* levels. The interpretation given by us is confirmed by the results of a study of the photoabsorption spectrum of potassium,[5] in which the presence of a large number (> 100) of autoionizing states in the energy interval of 14.5 to 31 eV (the energy was measured from the ground state of the ion) was established.

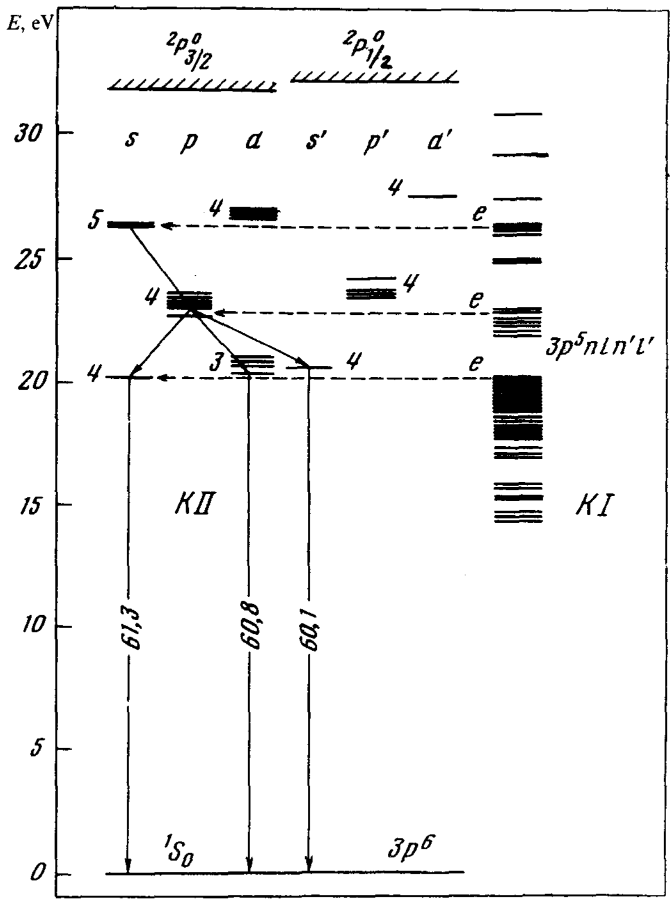

FIG. 2. Diagram of the KII energy levels and of the autoionization of KI states.

Finally, it can be said that the effective capture of the incident electrons by potassium ions in the autoionizing levels of the neutral atom, with subsequent resonance increase of the population of the excited states of the ion, greatly exceeds the process of direct excitation of the *p* electron in the resonance levels of the potassium ion.

[1]K.T. Dolder and B. Peart, Rep. Prog. Phys. **39**, 693 (1976).

[2]D.H. Crandall, P.O. Taylor, and G.H. Dunn, Phys. Rev. **A10**, 141 (1974).

[3]I.P. Zapesochnyiĭ, V.A. Kel'man, A.I. Imre, A.I. Dashchenko, and F.F. Danch, Zh. Eksp. Teor. Fiz. **69**, 1948 (1975) [Sov. Phys. JETP **42**, 989 (1975)].

[4]I.S. Aleksakhin, V.S. Vukstich, and I.P. Zapesochnyiĭ, Zh. Eksp. Teor. Fiz. **66**, 1973 (1974) [Sov. Phys. JETP **39**, 971 (1974)].

[5]M.W.D. Mansfield, Proc. Roy. Soc. Lond. **A346**, 539 (1975).