EXCITATION OF AUTOIONIZATION STATES OF ALKALI-METAL ATOMS IN SLOW COLLISIONS WITH INERT-GAS ATOMS

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Excited states of the atoms Cs, Rb, and K with energies higher than the first ionization potential were observed by Beutler [1 - 3] back in the 30's, although data on how these states become manifest in various physical processes have appeared only recently. Studies of the photoabsorption cross sections of alkali metals in the vacuum ultraviolet (e.g., in [4]) and experiments on the ionization of alkali-metal ions by electron impact [5, 6] have shown that the ionization states exert an appreciable influence on the behavior of the corresponding cross sections. In our earlier paper [7] we investigated, by the blocking potential method, the spectra of the electrons that appear when alkali-metal atoms are ionized in slow collisions (energy of incident alkali atom $T \leq 3000$ eV) with He and Ne atoms. It was established that intense discrete groups of electrons are observed for definite combinations of the collision partners (for example Cs and Ne, Rb with He, etc). It was proposed that the appearance of these groups is connected with the excitation of autoionization states of the alkali-metal atoms during the collision process, since no noticeable ionization of the inert gas was observed in the investigated range of incident-particle energies.

We have now investigated the energy spectra of the electrons emitted in such collisions with the aid of an electrostatic analyzer. Our aim was to determine in greater detail the structures of the observed discrete groups of electrons.

As before [8], the beam of fast alkali-metal atoms was obtained by resonant charge exchange. It entered a collision chamber filled with the inert gas at a pressure $\sim 5 \times 10^{-4}$ mm Hg. The electrons emitted upon collision with the alkali-metal atoms were observed at an angle of 90° to the beam direction. They were energy-analyzed with an electrostatic analyzer with resolution $\Delta E/E = 1:15$, and then accelerated to 11 keV and registered by an electron detector. The electron counting rate, at a constant intensity of the beam of fast alkali atoms, was plotted automatically as a function of the electron energy. The analyzer energy scale in the 5 - 35 eV range was obtained by calibrating the analyzer with an electron gun having an oxide cathode.

We studied the electron energy spectra for the pairs Cs and Ne (T = 2950 eV) Rb and He (T = 1750 eV), and Na and Ne (T = 580 eV), for which the results of the earlier study revealed the presence of intense discrete electron groups in the spectra.

As expected from the results of the earlier work, the electron spectrum for the Cs - Ne pair (T = 2950 eV), which is not shown in the figure, reveals a single intense maximum at an electron energy E = 8.5 eV and with a width at half-height $\Delta E = 0.6$ eV. This maximum can be naturally ascribed to the lowest autoionization state of Cs, namely $(5p)^2\ 6s^2\ {}^2P_{3/2}$ (E = 8.4 eV) (the energy of the autoionization states is reckoned throughout from the boundary of the continuous spectrum of the alkali-metal atom), since the next autoionization state of Cs, $(5p)^5 6s^2\ {}^2P_{1/2}$, would be expected, according to [3], at E = 9.6 eV. Within the limits of the

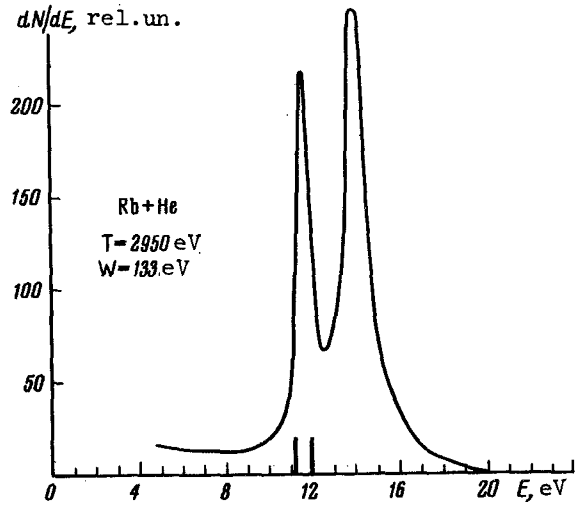

Fig. 1

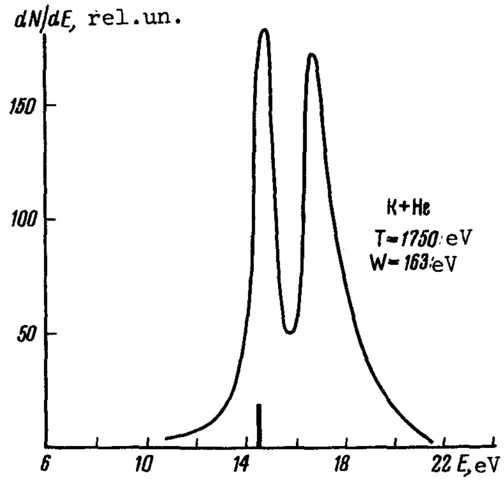

Fig. 2

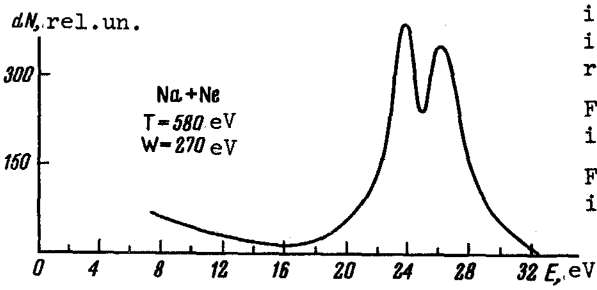

Fig. 3

Fig. 1. Energy spectrum of electrons produced by ionization of Rb colliding with He atoms. Here and in the other figures, W is the kinetic energy of relative motion of the colliding particles.

Fig. 2. Energy spectrum of electrons produced by ionization of K colliding with He atoms.

Fig. 3. Energy spectrum of electrons produced by ionization of Na colliding with Ne atoms.

sensitivity of our measuring setup, we observed no electrons with this energy in the spectrum.

Figures 1, 2, and 3 show respectively the measured electron spectra for the pairs Rb and He (T = 2590 eV), K and He (T = 1750 eV), and Na and Ne (T = 580 eV). As seen from the figures, the energy spectra of the electrons are similar in all cases. The spectrum has two maxima, one narrow and the other broad. The vertical lines on the abscissa axes of Figs. 1 and 2 designate the electron energies corresponding to autoionization of the lowest levels (beyond the ionization boundary) of the alkali-metal atoms. These are the Rb doublet $(4p)^5 5s^2\ ^2P_{3/2}$ (E = 11.1 eV) and $(4p)^5 5s^2\ ^2P_{1/2}$ (E = 12 eV) and the analogous K doublet $(3p)^5 4s^2\ ^2P_{3/2}$ (E = 14.4 eV) and $(3p)^5 4s^2\ ^2P_{1/2}$ (E = 14.6 eV), which are known from investigations of photoabsorption in the vacuum ultraviolet. We see that the position of the first maxima in Figs. 1 and 2 agree well with the energy values designated by the vertical lines. The second maximum can also be attributed to autoionization of higher states of the atoms Rb and K, known from [2] and [4]. The presence of two intense maxima in the spectra correlates with the fact known from data on photoabsorption by the Rb and K atoms, that the intensely excited lower autoionization states are separated from the intensely excited higher autoionization states by a wavelength interval corresponding to an electron energy interval 1 - 2 eV.

Particular interest attaches to the electron spectrum for the Na - Ne case (T = 580 eV) shown in Fig. 3. With the same degree of reliability as in the cases of Rb and K, the two maxima in the electron spectrum can be interpreted as manifestations of autoionization states of sodium in the course of the (Na, Ne) collisions. In this case, the first maximum at E = 23.5 ± 0.5 eV can be ascribed, in analogy, to the lower autoionization doublet of states $(2p)^5 3s^2\ ^2P_{3/2,\ 1/2}$. The indicated auto-ionization states of Na were apparently observed for the first time.

Thus, the discrete electron groups observed in our investigation of the collisions of alkali-metal atoms with He and Ne atoms correspond to excitation of the same autoionization states as in the absorption of light. It should be noted that the corresponding maxima in the electron spectrum are very intense.

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GRAVITATIONAL EFFECT IN INTERFERENCE SPECTRA OF THE FINE STRUCTURE OF THE RAYLEIGH LINE

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We have obtained first results indicating an influence of the gravitational effect near critical stratification temperature of a binary solution on the magnitude of the speed of sound and on the refractive index of light. A new method, the gist of which is clear from Fig. 1, is proposed to observe this influence.

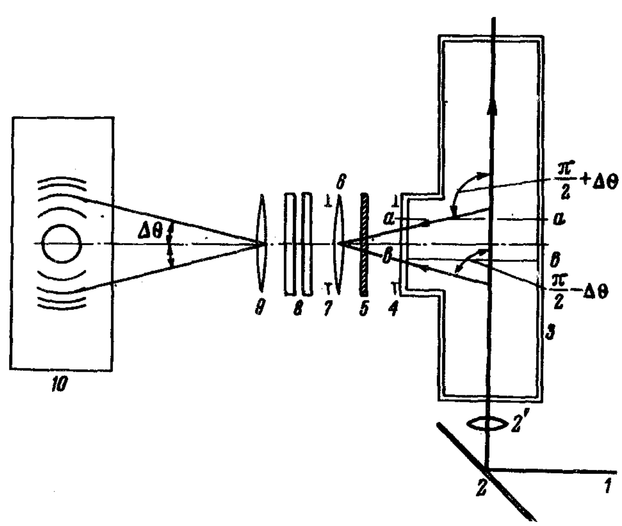

Fig. 1. Experimental setup: 1 - laser beam; 2 - flat mirror; 2' - long-focus lens; 3 - cell with solution, 140 mm high, 40 mm dia, diameter of side window 40 mm, aa - center of cell, bb - phase boundary after stratification; 4 - diaphragm; 5 - light filter; 6 - objective with focal distance f = 300 mm; 7 - diaphragm; 8 - Fabry-Perot interferometer, dispersion 0.5 cm^{-1}; 9 - objective, f = 500 mm; 10 - plane of spectrum.