Concerning the possibility of radiative decay of the collective levels of the argon atom

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(Submitted September 6, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 8, 464–467 (20 October 1976)

The x-ray spectrum of Ar in the 15–200 Å region was investigated with an aim at detecting the radiation of the collective vibrations of the electron shell of the atoms. No collective-vibration radiation was observed, possibly either because of the insufficient number of electrons in the Ar-atom shell or because of the low probability of the radiative decay of its collective levels.

PACS numbers: 32.10.Fn

Recent theoretical investigations[1,2] instil confidence that collective levels (CL) actually exist in an atom. This confidence is based on the fact that, as shown in [1], the lifetime of the excited CL is long enough to make it observable.[1)] The electon shell of the atom, excited to a CL, executes vibrations and can emit photons of frequency equal to the frequencies of the collective vibrations of the electron shell of the atom. These frequencies were calculated in [1,2] and for the Ar atom, in electron volts, they equal 247.3 and 648.7[1] and $184+198n$, where $n=0,1,2\cdots$.[3] The spectral lines with these energies lie in the soft x-ray region (wavelength interval 20—70 Å). In [3,4] they studied the emission spectrum of Ar in the wavelength region 50—65 Å, which was interpreted on the basis of the single-particle excitations of the electron shell of the atom. Recognizing that in [3,4] they investigated in detail only a narrow section of the spectrum, and that the approximations made in [1,2] could alter somewhat the true frequencies of the collective vibrations of the Ar atom, we have decided to search for the radiation due to the decay of CL in a wider region of the spectrum.

The experimental setup consisted of two main units—an x-ray tube with supersonic argon jet as the anticathode[5,6], and a grazing-incidence spectrometer

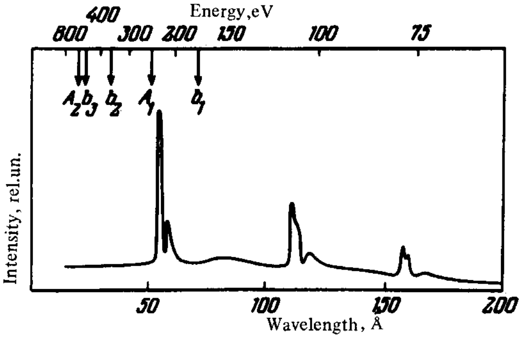

FIG. 1. Argon emission spectrum in the wavelength interval 15—200 Å (the intervals 15—50 Å and 50—200 Å were measured with the 6- and 2-meter gratings, respectively). A_1, A_2-calculated values of the excitation energy of the CL of the argon atom according to[1], B_1, B_2, B_3-according to[2].

RSM-500.[7] The spectrum was investigated under jet-outflow conditions (the pressure and temperature of the gas entering the nozzle were 2 atm and 550 °K), thus ensuring that the gas was monatomic.[8] The jet was excited with an electron beam of energy 1 keV and current density 0.4 A/cm^2. Two diffraction gratings having 600 lines/mm and curvature radia 6 and 2 m resolved the radiation into a spectrum in two wavelength bands, 15 – 60 and 50 – 550 Å. The radiation detector was a flow-through proportional counter.

Figure 1 shows the x-ray emission spectrum of Ar in the wavelength region 15 – 200 Å. The positions of the spectral lines of the possible emission of col-

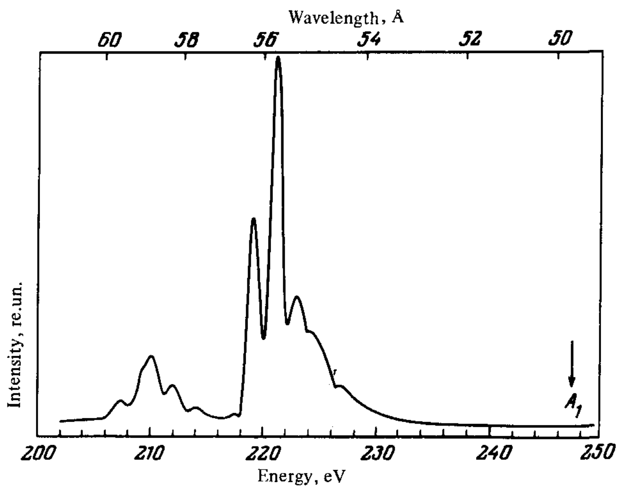

FIG. 2. Emission spectrum of argon in the region of the $L_{2,3} - M_1$ transition. The arrow indicated the position of one of the collective levels of the argon atom in accord with [1].

TABLE I.

Measured energy, eV	Transition	Transition energy, eV (published data)
207.4	$2p^5 3s^2 3p^6 (^2P^o_{3/2}) \to 2p^6 3s^2 3p^4 4d (^2S_{1/2})$	207.2 [9, 10]
210.1	$2p^5 3s^2 3p^6 (^2P^o_{3/2}) \to 2p^6 3s^2 3p^4 3d (^2S_{1/2})$	209.9 [9, 10]
212.1	$2p^5 3s^2 3p^6 (^2P^o_{1/2}) \to 2p^6 3s^2 3p^4 3d (^2S_{1/2})$	212.0 [9, 10]
214.1	$2p^5 3s^2 3p^6 (^2P^o_{1/2}) \to 2p^6 3s^2 3p^4 4s (^2S_{1/2})$	214.0 [9, 10]
217.4	$2p^5 3s^2 3p^5 (^1P_1) \to 2p^6 3s\, 3p^5 (^1P^o_1)$	217.6 [3]
219.2	$2p^5 3s^2 3p^6 (^2P^o_{3/2}) \to 2p^6 3s\, 3p^6 (^2S_{1/2})$	219.2 [9]
221.3	$2p^5 3s^2 3p^6 (^2P^o_{1/2}) \to 2p^6 3s\, 3p^6 (^2S_{1/2})$	221.3 [9]
223.0	$2p^5 3s^2 3p^5 (^1D_2) \to 2p^6 3s\, 3p^5 (^1P^o_1)$	222.2 [3]
223.0	$2p^5 3s^2 3p^5 (^3D_2) \to 2p^6 3s\, 3p^5 (^3P^o_{1,2})$	222.4; 222.6 [3]
223.0	$2p^5 3s^2 3p^5 (^3S_1) \to 2p^6 3s\, 3p^5 (^3P^o_{0,1,2})$	222.8 – 223.1 [3]
224.3	$2p^5 3s^2 3p^5 (^3D_1) \to 2p^6 3s\, 3p^5 (^3P^o_{0,1,2})$	223.7 – 224.0 [3]
226.6	$2p^5 3s^2 3p^5 (^1D_2) \to 2p^6 3s\, 3p^5 (^3P^o_{1,2})$	225.8; 226.0 [3]

lective vibrations of the electron shell of the Ar atom are marked by arrows. As seen from Fig. 1, one of these lines, A_1, is located in the region of the most intense emission peak. The section of the spectrum in the region of this peak was therefore measured with better resolution (~1 eV), using a diffraction grating with curvature radius 6 m (see Fig. 2). It follows from the presented data that at energies corresponding to excitation of collective vibrations of the electron shell, no emission lines are observed. Those emission peaks which are registered at other energy values can be attributed to transitions between single-particle levels of the Ar atom. Indeed, according to the data of[3,4], the intense peaks at 219.2 and 221.3 eV constitute a spin-orbit doublet produced in the $L_{2,3}-M_1$ transition. The satellite spectrum located on the lower-energy side of the $L_{2,3}-M$ doublet is emitted in a two-electron shake-up process, in which one $3p^6$ electron fills an $L_{2,3}$ vacancy, and the other is excited to a higher level of the atom. The resultant final states $3s^2 3p^4 ns(^2S_{1/2})$ and $3s^2 3p^4 nd(^2S_{1/2})$ are strongly mixed with the final state $3s3p^6(^2S_{1/2})$ of the x-ray $L_{2,3}-M$ transition. The satellite spectrum observed on the high-energy side of the doublet is produced in transitions in the doubly-ionized Ar atom. The initial state in such transitions is $2p^5 3s^2 3p^5(^{1,3}L_j)$, and the final state $2p^6 3s 3p^5(^{1,3}P_j)$.

Table I lists the values of the energies of all the lines observed in the Ar emission spectrum shown in Fig. 2. In addition, Table I indicates the transitions at which the spectrum is produced, and the transition energies determined from the published data. The emission lines registered in the regions of 115 and 160 Å (see Fig. 1) constitute the $L_{2,3}$ x-ray spectrum in the second and third diffraction orders.

Thus, in the emission spectrum of Ar, in the wavelength region 15—200 Å, no emission of the collective vibrations of the electron shell of the Ar atom has been observed. It cannot be concluded from this fact that there are no CL in the atoms in general and in the Ar atom in particular. The absence of collective vibrations of the electron shell of the Ar atom can be attributed to at least two causes, insufficient number of electrons in its *s* shell or the low probability of the radiative decay of the CL of the Ar atom in comparison with other possible CL decay channels. To ascertain the role of the first of the indicated causes, we have undertaken an investigation of the x-ray spectra of heavier noble gases, Kr and Xe. The result of this investigation will be published later.

In conclusion, we are sincerely grateful to Doctor of Physical-Mathematical Sciences T.M. Zikmina and to Candidate of Physical Mathematical Sciences A.S. Vinogradov for interest in the work and for help with the adjustment of the RSM-500 instrument.

[1)]The reference is to the quantum-level lifetime relative to what appears to be its most probable decay, into single-particle excited levels. Lifetimes relative to other possible quantum-level decays are even longer.

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