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HIGH-RESOLUTION AUGER SPECTRA OF LI, Be, B AND C EXCITED IN SINGLE GAS COLLISIONS

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Abstract. We have studied high-resolution Auger spectra of lithium, beryllium, boron and carbon excited in single gas collisions.

Despite the fundamental importance of electron correlation in highly excited atoms and ions [1], very few data exist for singly- and doubly core-excited states iso-electronic with He and Li. This work is concerned with the experimental study of projectile-Auger electron emission from fast moving Li, Be, B and C ion beams, which were passed through thin gas targets. For the first time we give a detailed analysis of the Auger-electron spectra for the low-Z elements. In particular we have studied iso-electronic sequences of the most prominent singly core-excited lithium-like and doubly core-excited helium-like states [2]. Furthermore, we have extracted free-atom K-shell binding energies for Be, B and C from our projectile-Auger spectra [3].

We have recently demonstrated that high resolution is obtained in projectile-Auger spectroscopy using single-collision gas excitation [4-6]. The Doppler width of the measured Auger lines can be further decreased by selecting observation angles close to zero degrees. In this work we have improved the resolution by decreasing the observation angle from 15° to 6.4° and the spectrometer acceptance angles to Δθ = 0.18° and Δφ = 2.86°. In this way, we achieve (i) a resolution better than 2 x 10⁻³, including kinematical line-broadening effects, and (ii) count rates of several thousands cps for the main projectile-Auger structures [2].

The Li, Be, B and C ion beams were supplied by the 600-keV heavy-ion accelerator at the University of Aarhus. Electrons ejected from the target region were analyzed by an electrostatic parallel-plate spectrometer which can be continuously rotated between 0° and 150°. A view of the target region is shown in Fig. 1. For normalizing purposes, the ion beam was collected in Faraday cup 2 for small observation angles (see Fig. 1). Typical target-gas pressures were 4.10⁻³ torr to ensure single-collision condition.

**Fig. 1 - View of the target region.**

The projectile-Auger electron spectra were studied for incident beam energies of 100 to 500 keV excited in single collisions with atomic and molecular targets such as He, Li, Ne, H₂, CH₄ and N₂. Helium, in particular was selected because of the small projectile scattering angle for K-shell excitation giving small Doppler broadening [2]. In addition helium is the simplest atomic target, which may facilitate an understanding of the collisional processes. On the other hand molecular targets such as CH₄ were found to
Fig. 2 - The high-energy part of the Li autoionization spectrum excited in (a) 200 keV Li$^+$ on CH$_4$, and (b) 300 keV Li$^+$ on He collisions. The structure shown corresponds to doubly core-excited two- and three-electron states.
give higher excitation probabilities for helium- and lithium-like doubly core-excited states.

A typical high-resolution Auger spectrum is presented in Fig. 2. The observed spectral features as indicated in Fig. 2 can be associated with doubly core-excited states in LiII and LiIII.

Whenever there is more than one series for a given $S$, $L$ and $\pi$, the mixings between the different configurations are so great that classifications based on single products of orbitals are not valid. For He-like states we use the notation $(N,na)(2S + 1)L \pi$, where $N$ is the inner-electron quantum number, $n$ is the outer-electron radial quantum number and $a = a, b, c, \ldots$. The letters $a$, $b$, etc. are assigned according to the energy of the lowest member of each series [1].

The lowest possible Auger decay in LiIII is $(2,2a)^1S \rightarrow (1s\pi^1S).$ This line is observed at 70.65 eV (peak 18). Peak 19 (see Fig. 2) originates from the $(2,2a)^3P^o$ state in LiII. Furthermore, peak 20 can be associated with the $(2,2a)^1D$ level. There might be a superposition of two lines in the region of peak 21, namely the $(2,2a)^1P^o \rightarrow (1s\pi^1P^o)$ and the $(2s^22p)^2P^o \rightarrow 1s2p^1P^o$ decays.

Autoionization lines observed between 78.13 and 83.36 eV (see Fig. 2) are expected to arise from doubly core-excited states in LiII. Another surprising feature is the strong population of $2s2\pi^1$ high angular momentum states such as $(2,3a)^3D$ and $^1D$, $(2,3a)^3F^o$ and $^1F^o$ and $(2,3b)^3D$ and $^1D$.

To conclude, Auger transition energies for many previously unknown states in Li, Be, B and C have been measured using the projectile-Auger-spectroscopy method [2]. These new data might be of particular importance to test and improve ionic wave functions including the effects of electron correlation.

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