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Comments

Comments are short papers which comment on papers of other authors previously published in the **Physical Review**. *Each Comment should state clearly to which paper it refers and must be accompanied by a brief abstract. The same publication schedule as for regular articles is followed, and page proofs are sent to authors.*

Comment on "Electric field ionization of foil-excited Rydberg states of fast heavy ions"

H.-D. Betz, J. Rothermel, and D. Röschenthaler
Sektion Physik der Universität München, D-8046 Garching bei München, Federal Republic of Germany
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We comment on the suitability of field ionization and x-ray observation for the investigation of Rydberg states in ion-atom collisions and clarify apparent discrepancies which have been recently communicated.

In a recent Rapid Communication, Kanter, Schneider, and Vager[1] reported on foil-excited Rydberg state populations of 125-MeV sulfur ions obtained by means of the field-ionization technique. These authors claim that their results concerning the absolute population of produced Rydberg states disagree with previously published findings[2,3] obtained from another technique which measures radiative decays of excited states. In this Comment we like to explain that there is no demonstrable discrepancy between the data of Kanter *et al.* and our measurements.

Field ionization and x-ray observation represent complementary techniques with respect to the investigation of heavy-ion Rydberg states. The first method can provide the absolute, total population of a certain range of Rydberg states (summed over principal and angular momentum quantum numbers n and l, respectively), but for heavy ions only very high shells can be ionized ($n \gtrsim 250$ in Ref. 1), and the method fails to give information on the charge state of the investigated atom or on the l distribution of Rydberg electrons. The x-ray technique allows to resolve decays from well-defined charge states and can test a given initial n,l distribution for values of n which are not too large ($2 \leq n \lesssim 120$ in Refs. 2 and 3), but total populations are directly measurable only for states with low quantum numbers and are out of reach when states with too long lifetimes become involved. Kanter *et al.*[1] measure a total Rydberg yield for states in the range $250 \lesssim n \lesssim 650$, $Y_R = 10^{-5}$ atoms/ion. Assuming an n^{-3} variation this yield is converted into a population distribution, $P(n) = 1.5n^{-3}$.

In our previous work[2] we measured K-shell x rays of 127-MeV sulphur ions which are emitted far behind the target foil and represent decays of Rydberg states in the range $n \lesssim 120$ (Fig. 1). Without any sophisticated calculation one can conclude that the observed large ratio between Ly-α and Ly-β intensities, $R \cong 90$, signifies surprisingly strong population of high-l states. By contrast, when it is assumed that the observed Rydberg states are produced primarily by capture of target electrons[1] one would expect a low-l population for the investigated fast collision, in marked contrast to our experiment. To illustrate further the difficulties with this capture-based model we determined in Ref. 2 that hypothetical low-l population, $P_L(n) = (30 \pm 15)n^{-3}$ atoms/15^+ ion, which reproduces approximately the measured intensity of

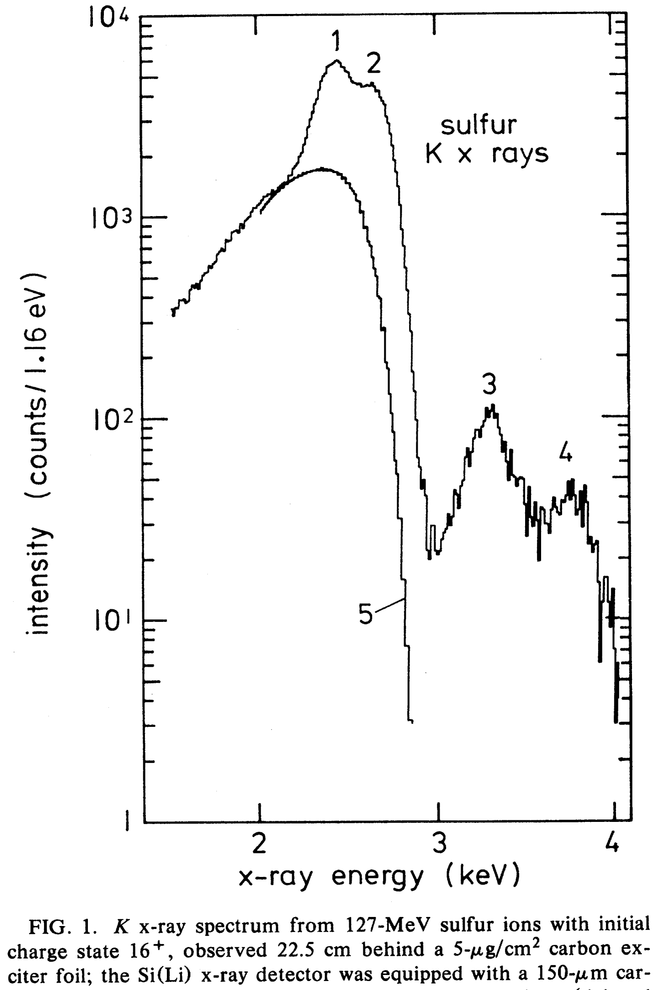

FIG. 1. K x-ray spectrum from 127-MeV sulfur ions with initial charge state 16^+, observed 22.5 cm behind a 5-μg/cm^2 carbon exciter foil; the Si(Li) x-ray detector was equipped with a 150-μm carbon absorber. 1: He-like transitions; 2: H-like transitions (delayed Ly-α, $M1$ decay of $2s$ state); 3: delayed Ly-β ($3p$-$1s$); 4: $np \rightarrow 1s$ ($n \geq 5$); 5: calculated photon intensity due to two-photon decays of H- and He-like s states. $K\beta$ transitions from He-like ions (near 2.9 keV) are too weak to be clearly seen. Inspection of the large ratio of Ly-α and Ly-β intensities, together with well-known branching ratios for radiative transitions, reveal a relatively strong population of high-l states which decay prefentially via $3d \rightarrow 2p \rightarrow 1s$.

the Ly-β line (while giving much too little Ly-α intensity), and we showed that such a magnitude of P_L can hardly be accounted for from known capture cross sections and last-layer target thickness. It is obvious that we do not claim that the test population P_L reflects the *real* distribution, and therefore it is not justified that Kanter *et al.*[1] interpret the difference between P_L and their population P as a discrepancy.

Furthermore, we do not agree with the opinion of Kanter *et al.*[1] that the x-ray technique is not suited to study the role of last-layer capture in the formation of Rydberg states. On the contrary, the technique is sufficiently sensitive to reveal at least two important features of the actually operating mechanism: (i) the l distribution is not at all as expected from electron-capture theory,[2] and (ii) direct capture of target electrons plays no dominant role.[3] Interestingly, a recent study of convoy-electron production revealed also the relative unimportance of target-electron transfer.[4] These very specific findings are indeed in pronounced contradiction to the claim by Kanter *et al.*[1] that their experimental yield number Y_R could be well understood by invoking last-layer capture.

A comprehensive description of results on foil- and gas-excited Rydberg states is in preparation.

[1]E. P. Kanter, D. Schneider, and Z. Vager, Phys. Rev. A **28**, 1193 (1983).
[2]J. Rothermel, H.-D. Betz, F. Bell, and V. Zacek, Nucl. Instrum. Methods **194**, 341 (1982).
[3]H.-D. Betz, D. Röschenthaler, and J. Rothermel, Phys. Rev. Lett. **50**, 34 (1983).
[4]Y. Yamazaki and N. Oda, Phys. Rev. Lett. **52**, 29 (1984).