Comment on "Energy-Dependent Excitation Cross Section Measurements of the Diagnostic Lines of Fe XVII"

In a Letter by Brown *et al.* [1], measurements of the electron-impact excitation (EIE) cross sections for dominant x-ray lines from Fe XVII ions and radiative recombination (RR) of the beam electrons into the M-shell levels of the source ions were reported. The EIE cross sections were determined by normalizing to the measured intensity of the RR peaks, which were independently normalized to the theoretical RR cross sections σ calculated [1] by the Dirac-Slater method. It was claimed in the Letter that available theoretical EIE cross sections σ_{3C} were in error (higher) by $\gtrsim 25\%$ compared to their experimental values.

The problem with the determination of absolute values of the measured EIE cross sections by normalizing the measured intensity of RR peaks to the theoretical RR cross sections is that only the RR channel is taken into account in the Letter, while the polarization radiative recombination (PRR) channel [2] is overlooked. In this channel, the photon is emitted not by the incident electron, as in the RR channel, but by core electrons. We show here that the inclusion of the PRR channel leads to an increase (up to 26%) in RR and hence EIE cross sections.

Furthermore, we verify by inspection RR cross sections σ used in the Letter for normalizing by comparison with our calculations of RR cross sections $\tilde{\sigma}$ by the Dirac-Fock method [3]. The values of RR cross sections $\tilde{\sigma}$ and σ in barn at electron-impact energy of 964 eV are listed in Table I, together with uncertainties $\Delta = (\sigma - \tilde{\sigma})/\tilde{\sigma}$.

PRR is related [2] to the polarization bremsstrahlung with coherent radiation due to virtual excitations (polarization) of the ion core electrons by the Coulomb field of projectiles. The RR and PRR amplitudes are shown in Figure 1.

Thin lines in Feymann's diagrams describe the transition of the incident electron with the energy ε into the bound final f state with the energy ε_f. Thick lines "c" relate to the core electrons and "v" to their virtual states. Dashed lines denote the emitted photon with the energy ω. Wave lines indicate the Coulomb interaction.

Since the initial, ε, and final, f, electron states in RR and PRR amplitudes are identical, there is quantum interference between them. At energies of dielectronic resonances, PRR is indistinguishable from an interfering part of the dielectronic recombination (DR) leading to the final state with a single excited electron. In energy regions free from DR resonances, PRR is the dominant process, where its main effect is the enhancement of the RR background. The interference between the amplitudes is responsible for the enhancement of the total cross section $\sigma_{\text{tot}} = \sigma_{\text{RR}} + \sigma_{\text{int}} + \sigma_{\text{PRR}}$. The contribution into the interference term σ_{int} comes from all virtual electron core excited states, including the continuum.

TABLE I.

$n\ell j$	$\tilde{\sigma}(b)$	$\sigma(b)$	$\Delta(\%)$
$3s_{1/2}$	33.9	35.6	5
$3p_{1/2} + 3p_{3/2}$	84.7	89.4	6
$3d_{3/2} + 3d_{5/2}$	29.5	31.6	7

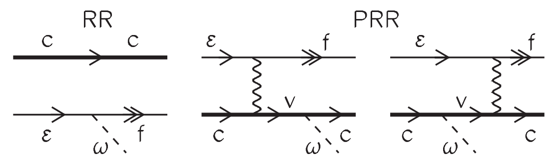

FIG. 1.

We estimated the enhancement factor $F = \sigma_{\text{tot}}/\sigma_{\text{RR}} \simeq 1 + \sigma_{\text{int}}/\sigma_{\text{RR}}$ using the analytical "stripping" approximation [2] and the Dirac-Fock method. On average, F equals 1.21 for RR into the $3\ell j$ levels of Fe^{16+}. Comparison between our approximate and exact results for the Kr^{26+} ion [2] suggests the uncertainty in F to be $\simeq 4\%$. Therefore, the corrected value for Fe^{16+} is $F = 1.26$. The enhancement factor due to the inclusion of PRR along with $\Delta \simeq 6\%$ results in the 20% increase in EIE σ_{3C} given in [1]. This eliminates the puzzling discrepancy between experimental and theoretical results.

It should be emphasized that we use the modern, fully relativistic methods (see, e.g., our review [3]) and the advanced method by Korol *et al.* [2] in calculations of RR and PRR, respectively. In their method, the part of DR noninterfering with RR is excluded from the very beginning and all virtual core excitations including into continuum are taken into account. It is a problem to meet these conditions in other methods and therefore to describe correctly the PRR effect, e.g., in the close coupling calculations of the unified RR + DR cross section.

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