Electron-impact ionization for P-like ions forming Si-like ions

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Synopsis We have calculated electron-impact ionization (EII) for initially P-like systems for ions with an even proton number Z from S^{+} to Zn^{15+}. We used the flexible atomic code (FAC) which is based on a distorted-wave (DW) approximation. In our work, $3l \to nl'$ ($n = 4-35$) excitation-autoionization (EA) channels near the $3p$ direct ionization threshold and $2l \to nl'$ ($n = 3-10$) EA channels at the higher energies are included, along with the detailed branching ratios. Our calculated EII cross sections are compared both with previous FAC calculations, which omitted many of these EA channels, and with the available experiments.

A reliable analysis and modeling of plasma spectra relies on accurate charge state distribution (CSD) calculations. The CSD for collisionally ionized plasma is determined by the balance between electron-impact ionization (EII) and electron-ion recombination. There are many challenges in generating the required EII data.

Experimental EII cross sections measurements have usually been limited to single pass experiments using ion beams with an unknown population of metastable levels. However, using an ion storage ring one can store many ions long enough so that essentially all of the metastable levels can radiatively decay to their ground states. Recently EII measurements at TSR have been reported for P-like Fe^{11+} [1].

A comparison with the EII calculations for Fe^{11+} by Dere [2], using FAC [3], show a discrepancy with the TSR work. The theory falls below the measurement near the $3p$ direct ionization threshold and lies above the measurement at higher energies. We have performed an improved FAC calculation, helping to resolve much of these discrepancies [4]. In our calculation, we take into account the $3l \to nl'$ ($n = 4-35$) excitation-autoionization (EA) channels near the threshold and the $2l \to nl'$ ($n = 3-10$) EA channels at higher energies, along with their detailed branching ratios [4]. At collisional ionization equilibrium (CIE) temperatures for Fe^{11+} formation, the rate coefficient derived from our calculation lies within 11% of the experimentally derived rate coefficient and is in better agreement with the measurement [1] than the previous FAC results of Dere [2], which shows up to 25% difference from the measurement.

We have extended our EII calculations for Fe^{11+} to P-like ions with an even proton number Z from S^{+} to Zn^{15+}. The total EII Maxwellian rate coefficients for these ions are shown in Figure 1. The rate coefficients for the ions derived from our new FAC calculation show 10–100% difference from the earlier FAC rate coefficients of Dere [2] at temperatures around the CIE peak abundance of each ion.

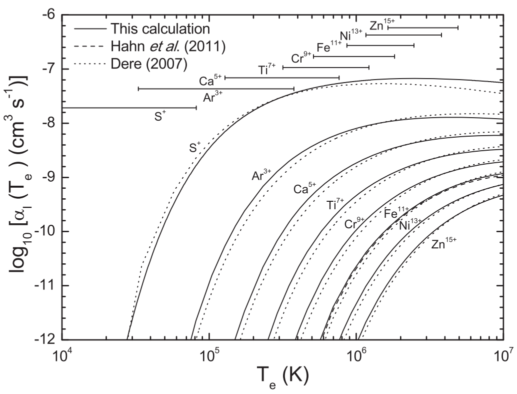

Figure 1. EII rate coefficients for the ground state P-like ions forming Si-like ions derived from the present calculation. Also shown are the rate coefficients derived from the recent experiment of Hahn *et al.* [1] for Fe^{11+} and the previous FAC calculation by Dere [2]. The CIE temperature regime for each ion is given by the horizontal bars [5].

References

[1] M. Hahn *at al.* 2011 *Astrophys. J.* **729** 76

[2] K. P. Dere 2007 *Astron. & Astrophys.* **466** 771

[3] M. F. Gu 2008 *Can. J. Phys.* **86** 675

[4] D.-H. Kwon and D. W. Savin 2012 *Phys. Rev. A* **86** 022701

[5] P. Bryans, E. Landi and D. W. Savin 2009 *Astrophys. J.* **691** 1540

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