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Electron impact ionization measurements at the Heidelberg heavy ion storage ring TSR

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Synopsis Reliable rate coefficients are needed in order to model the charge state distributions (CSDs) of astrophysical plasmas. We are carrying out electron impact ionization (EII) measurements for astrophysically important ions using the heavy ion Test Storage Ring (TSR) at the Max-Planck Institute for Nuclear Physics in Heidelberg, Germany. These storage ring measurements provide unambiguous data from essentially pure ground-state ion beams.

Reliable ionization balance calculations are needed to analyze spectra from a wide range of cosmic sources including photoionized objects such as AGNs and X-ray binaries and electron ionized objects such as stars, supernovae, galaxies, and clusters of galaxies. These theoretical CSDs depend in turn upon the underlying atomic data. Of particular importance are rate coefficients for EII, which is the dominant ionization mechanism in collisionally ionized plasmas, and for dielectronic recombination (DR), which is the dominant electron-ion recombination mechanism for most ions.

We are measuring EII and DR using TSR. A major limitation of previous work has been the difficulty of producing well-characterized ion beams. Most ion sources generate beams with unknown fractions of metastable and ground state ions. The storage ring approach solves this problem by storing the ions long enough that metastable levels radiatively decay to the ground state before data are collected.

We have measured DR for at least one ion in every isoelectronic sequence from Li-like through K-like. These data have provided benchmarks that have led to substantial improvements in DR theory. Reviews of our experimental work are given in [1, 2].

Recently we have expanded our work to study EII. Figure 1 shows a TSR EII cross section measurement [3] compared to the crossed beams experiment of [4] and a recent distorted wave calculation [5]. The measurement of [4] is about 30% larger than our TSR result due to the presence of metastables in their experiment. Standard CSD data, such as those of [6], have incorporated the crossed beams results and inherited the systematic errors from the metastable ions. Figure 1 also shows that there are clear differences between the TSR data and modern EII theoretical results. Our measurements can provide useful benchmarks for such calculations.

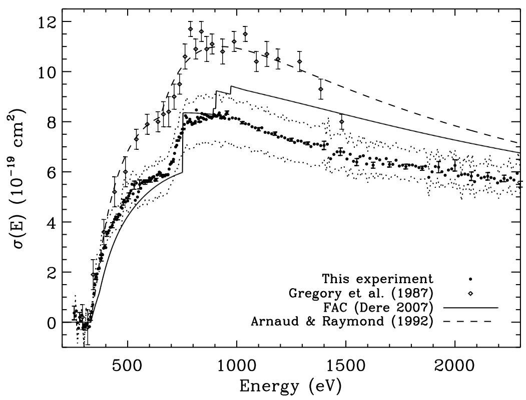

Figure 1. Measured EII cross section for Fe^{11+} forming Fe^{12+} [3] (filled circles). Error bars at selected points indicate the 1σ statistical uncertainty and dotted curves illustrate the estimated 1σ systematic uncertainty. Also shown are the crossed beams result of [4] (diamonds), the data used in the CSD calculations of [6] (dashed line), and a distorted wave calculation [5] (solid line).

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