§16. Evaluation of Electron Impact Excitation Rate Coefficients for Fe M-shell Ions

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Spectroscopy is one of the most common diagnostic methods for various plasmas. Spectral line intensities and intensity ratios are used for diagnosing plasma temperature and density, or ion abundance. The relationship between line intensity and plasma temperature and density is usually given by a theoretical kinetic model in which line intensities are calculated from population densities of excited states. Electron impact excitation is one of the important processes which governs population densities. Reliable atomic data for electron impact excitation rates are necessary for plasma diagnostics.

Iron is one of the abundant elements in laboratory plasmas and in space. Iron abundance is often used as an index of heavy element abundance in space, such as intra-cluster medium, inter-galactic medium, hot gas in galaxies, inter-stellar medium, and the sun. Iron ions are one of major impurities in laboratory plasmas.

Iron M-shell ions are observed in transition region of the sun and planned to be measured by the EUV Imaging Spectrometer mounted on the SOLAR-B solar physics satellite which is scheduled for launch in 2006. In order to examine dynamics of the transition region, plasma diagnostics by the spectral lines are quite important and reliable theoretical model with reliable atomic data are necessary.

In this work we evaluate existing atomic data of electron impact excitation rate coefficients for M-shell Iron ions (Fe IX – Fe XVI) and give a set of recommended data. In case of Fe XIII we also make a fitting of the recommended data to an analytical form for easy use for plasma modeling and diagnostics [1,2].

Many theoretical studies on the excitation rate coefficients for Fe ions were done, but the experimental study is quite few. We examine the theoretical methods for calculating excitation rate coefficients with checking mainly the following points: (1) a number of levels included in the calculation, (2) treatment for configuration interaction, (3) a number of partial waves, (4) energy range, (5) relativity treatment, and (6) energy mesh for integrating cross sections to obtain rate coefficients. The R-matrix method is usually better than the distorted-wave method because the former can take into account the resonance effect, which affect the rate coefficients at low temperature region largely. But the R-matrix method has limitation for high energy region of electron collision, so we need to pay attention to the valid temperature range of the rate coefficients. Considering all available data we select data as recommended data for each Fe ion. For Fe XIII we fit all the rate coefficients to analytic formulae for convenience of applications.

Figure 1 shows an example of excitation rate coefficients. Data calculated by using the full relativistic R-matrix code by Aggarwal and Keenan (2005) are the best for the case of Fe XIII ion.

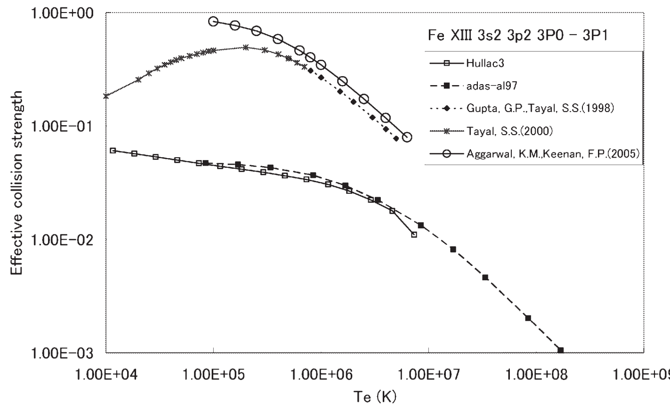

Fig.1 Excitation rate coefficient for $3s^23p^2\ {}^3P_0 - {}^3P_1$ transitions of Fe XIII ion as a function of electron temperature. Open circles are data calculated with full relativistic R-matrix code by Aggarwal and Keenan[3]. Diamonds and stars are calculated by semi-relativistic R-matrix code[4,5]. Solid squares are calculated by relativistic distorted wave method by Hullac code[6]. Open squares are calculated by distorted wave method from the ADAS database[7,8].

References

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