§19. Cross Section Database for Carbon Ions: Electron-impact Excitation, Ionization, and Charge Exchange in Collisions with Hydrogen Atoms

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diagnostics and energy-loss calculations in fusion plasmas. Charge-exchange process of carbon ions with hydrogen atoms also provides a useful plasma diagnostics. In this work, we have constructed a set of cross sections for such processes. As a basis for this cross section set we have used the available experimental and theoretical data from the literature and critically assessed their accuracy.

There exist numerous theoretical cross section data for electron-impact excitation of carbon ions. Previously, Itikawa et al. [1] compiled cross sections reported before 1985, assessed them for carbon ions (C^+-C^{5+}) as well as oxygen ions (O^+-O^{8+}), and fitted their recommended values to an analytical formula. Except for optically allowed transitions, all electron-impact excitation cross sections are scattered, and it has been sometimes difficult to determine the recommended data. We have carefully chosen reliable electron-impact data from references. Once the recommended cross sections were determined, a fit was made, which facilitates their applications. In most cases, we fitted the collision strength Ω into the analytical formula:

$$\Omega_{if}=A+B/X+C/X^2+D/X^3+E\ln X,$$

where A, B, C, D, and E are the fit coefficients, X the electron energy scaled by the transition energy, that is $X=E/V_{if}$. Figure 1 shows an example of our results, where we present the case of the C^{5+} 1s→2s transition.

Electron-impact ionization of carbon ions has been extensively studied both experimentally and theoretically. The experimental measurements and theoretical calculations agree fairly well with each other. The recommended cross section for electron-impact ionization is parametrized by the expression

$$\sigma\left[cm^2\right]=\frac{10^{-13}}{IE}\left\{A_1\ln(E/I)+\sum_{i=2}^{N}A_i\left(1-\frac{I}{E}\right)^{i-1}\right\},$$

where the collision energy E and ionization potential I are expressed in eV units and A_i are fitting coefficients. An example is shown in Fig. 2, where we present the ionization of C^{5+}.

There also exist numerous theoretical and experimental results for charge exchange processes in collisions of carbon ions with hydrogen atoms. Particularly the C^{6+}+H collisions are the most studied processes. The recommended cross sections are fitted to analytic fit functions such as

$$\sigma\left[cm^2\right]=10^{-16}\times\frac{a_1\exp\left[-\left(a_2/E\right)^{a_3}\right]}{1+\left(E/a_4\right)^{a_5}+\left(E/a_6\right)^{a_7}},$$

where the collision energy E is expressed in eV/amu units and a_i are fitting parameters. An example is shown in Fig. 3.

In summary, we have studied electron-impact excitation, ionization of atomic carbon ions, and charge exchange for carbon ions. More than 100 processes have been treated. Although we have shown only examples of our results, all our results will be published in Atomic Data and Nuclear Data Tables.

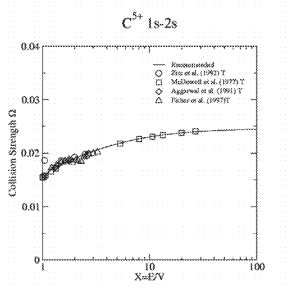

Fig. 1. Recommended electron-impact collision strength for the C^{5+} 1s→2s transition with the original collision strengths from the literature.

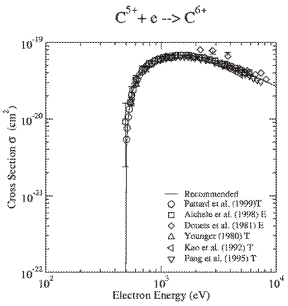

Fig. 2. Recommended cross section for the electron-impact ionization of C^{5+} as well as the original data from the literature.

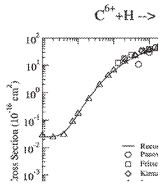

Fig. 3. Recommended cross section for the charge exchange between C^{6+} and H, as well as the original data from the literature.

Reference

1) Y. Itikawa et al., Atomic Data Nucl. Data Tables **33**, (1985) 149