§7. Recommended Collisional Database for Helium Atoms

Ralchenko, Yu. V. (Weizmann Inst. Sci., Rehovot, Israel),
Janev, R.K. (Macedonian Acad. Sci., Skopje, Macedonia),
Bray, I. (Flinders Univ., Adelaide, Australia),
De Heer, F.J. (FOM Inst. At. Mol. Phys., Amsterdam, The Netherlands), Kato, T.

Helium is the most important impurity on a D-T fusion reactor plasma generated in the plasma burning process. Its exhaust from the fusion reactor is one of the essential conditions for maintaining the plasma burn conditions. The helium removal from the reactor is achieved by its transport in the plasma edge (more specifically, in the divertor chamber), where it is neutralized in charge exchange collisions with the hydrogen gas. The transport of ionized and neutral helium in the divertor chamber is largely determined by its collision processes with plasma particles and the other edge plasma constituents. Therefore, for modeling the helium transport (and its other properties) in the plasma edge, the cross sections of its collision processes with all plasma constituents are required. Neutral helium atom beams may be injected into fusion plasmas for heating and/or diagnostic purposes. A He-beam diagnostics is now being planned at JET. Both the He-transport modeling in divertor regions and the energetic He-beam attenuation calculations in the main plasma require a collisional-radiative model for helium which includes all the collisional and radiative processes for all atomic excited states as well as the collision processes induced by electron, proton and multicharged ion impact. While the collisional cross section information for He is fairly abundant [1-3], it is related mainly to the processes involving the helium ground state. Also, no attempt has so far been made to undertake a critical assessment of the entire data information for He, except for the excitation cross sections from the ground state [4].

The present collisional database for He atoms is intended to respond to the needs of fusion researcher studying the He transport in divertors and He attenuation of energetic beams penetrating a fusion reactor plasma. The following collision processes are considered for the He atom being either in the ground or in the excited state:

1) excitation and ionization by electron impact,
2) excitation, ionization and electron capture by proton impact, alpha particle impact and multicharged ion impact.

The singlet and triplet series of electronic states are treated separately, and the electron-impact induced transitions between these two systems of states are also included in the database. All states with $nl \leq 4f$ are treated individually, and the states with $n > 4$ are considered as degenerate. For the transitions to and from the n > 4 states, suitable cross section scaling relations have been derived. For a large number of electron impact transitions both from the ground and excited states, new convergent close coupling (CCC) calculations have been performed to achieve a high accuracy of the data. In the collisions of He with alpha particles and multiply charged ions, beside the one-electron process, two-electron processes (such as double ionization double capture and transfer ionization) have also been included in the database. For the collision processes of He with multiply charged ions, in charge state greater than two, appropriate cross section scaling relationships were used.

All the evaluated/recommended cross sections have been presented by analytic fit functions which preserve the correct asymptotic behavior of the individual and scaled cross sections. These fits (accurate to a few percents in most of the cases) have been used to generate reaction rate coefficients in a broad temperature range. Some examples of evaluated data sets, together with their fits are shown in Figs. 1 and 2.

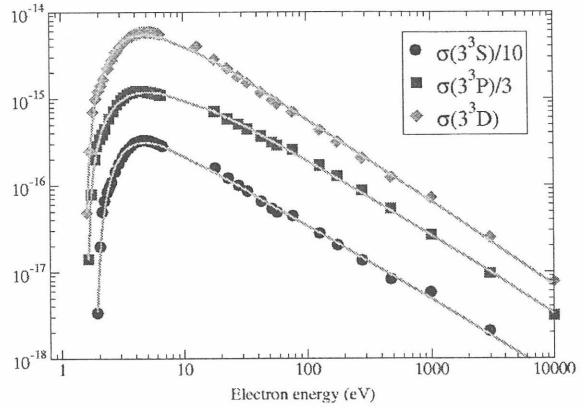

Fig. 1. Recommended electron impact ionization cross sections from some of the n=3 states of He I.

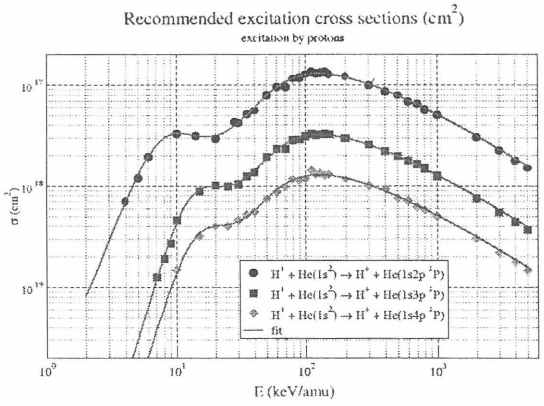

Fig. 2. Recommended excitation cross sections by protons.

References

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[4] Atomic and Plasma Matter. Int. Data Fusion, vol. 3, 1992 (IAEA, Vienna).