Dr Brendan M McLaughlin

Centre for Theoretical Atomic, Molecular and Optical Physics (CTAMOP)
School of Mathematics and Physics, Queen's University of Belfast
Belfast, BT7 1NN, UK

Title: Valence and inner-shell photoionization of trans-Fe and light atomic elements for astrophysical applications.

Abstract

Photoionization of atomic elements is an important process in determining the ionization balance and hence the abundances of elements in photoionized astrophysical nebulae. It has recently become possible to detect neutron n-capture elements (atomic number $Z>30$) in a large number of ionized nebulae [1,2]. These elements are produced by slow or rapid n-capture nucleosynthesis (the s-process and r-process, respectively). Measuring the abundances of these elements helps to reveal their dominant production sites in the Universe, as well as details of stellar structure, mixing and nucleosynthesis. These astrophysical observations provide an impetus to determine the photoionization and recombination properties of n-capture elements. Planetary nebulae (PNe) progenitor stars may experience s-process nucleosynthesis, in which case their nebulae will exhibit enhanced abundances of trans-iron elements. The level of s-process enrichment for individual elements is strongly sensitive to the physical conditions in the stellar interior.

Accurate assessment of elemental abundances in astrophysical nebulae can be made from the direct comparison of the observed spectra with synthetic non-local thermodynamic equilibrium (NLTE) spectra, if the atomic data for electron and photon interaction processes are known with sufficient accuracy. Experiments on heavy trans-Fe atomic ions at third generation synchrotron radiation source, such the Advanced Light Source (ALS) in Berkeley, California, USA, SOLEIL in Saint-Aubin, France, ASTRID in Aarhus, Denmark and PETRA III, in Hamburg, Germany, have all highlighted the need for high quality theoretical work to fully interpret experimental results. A recent developed theoretical code for parallel computing architectures [3-4] (incorporating the necessary relativistic effects within a Dirac-equation formulation) has been used to perform detailed photoionization cross section calculations on a variety of atomic ion species, e.g.; Fe [3], Se [4], Kr [5,6], Ar [8], Xe [5] and W [7], in their low stages of ionization.

For X-ray photon interactions with light atomic elements, e.g., C, N and O and their iso-electronic sequences [9-15] we used the established R-matrix with pseudo-states approach (in *LS* or intermediate coupling) to obtain cross-sections which are compared with high resolution synchrotron measurements and lower resolution satellite observations.

Such comparisons are essential and serve as the ultimate benchmark for our work in order to have confidence in the atomic data to be incorporated into standard astrophysical modeling codes such as CLOUDY, XSTAR and AtomDB.

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