Reliable atomic data for fusion research and astrophysics: Benchmarking calculations for highly charged ions

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Fusion research relies on spectroscopic diagnostics and modelling of atomic processes in plasmas. Similarly, astrophysics also requires large atomic databases to interpret observations. Due to continuous improvements of diagnostic systems in terms of both resolution and accuracy, the perspective of further developments in this field emphasizes the need for accurate and reliable atomic physics data. This is crucial for highly charged ions (HCI), a huge class of atomic systems of which the sheer size precludes full experimental coverage. Reliance on calculations based on state-of-the-art atomic structure codes such as Flexible Atomic Code (FAC) and other widely used packages implies a necessity for systematic benchmarking of their results against accurate laboratory data. Transition energies and cross sections for excitation, ionization, recombination and charge transfer have to be provided. Their accuracy has to enable discriminating between various theoretical models and finding the most appropriate ones. Establishing solidly founded standard benchmarks is thus essential. This applies to elements used in the wall materials of fusion reactors, those investigated in present and future astrophysics missions, as well as in other technological applications.

In terms of both variety of investigated species and data accuracy, the electron beam ion trap (EBIT) has proven to be the most efficient workhorse for HCI applications. Emission lines ranging from the X-ray to the optical domain for ionic species from lowly charged ions of light elements to the highest charge states of the heaviest elements have been measured and compared to theory. Cross sections and lifetimes have been studied in great detail. However, recent developments in spectroscopic equipment and theoretical methods call for even more accurate and systematic work. At synchrotron radiation sources and free-electron lasers, there is a need for more precise X-ray photon-energy standards. Moreover, several proposals regarding the use of HCI for atomic clocks in the optical and the vacuum-ultraviolet regions have been put forward in the last decade. I will present some of those results, compare them with theory and discuss the need for further research in the fields of experiment and theory, accompanied by the establishment of an expanded data base for accurate benchmarked reference data supported by IAEA.