M-shell Rebinding in Hot, Solid-density Mg and Al

Thomas Gawne

Center for Advanced Systems Understanding (CASUS), D-02826 Görlitz, Germany
Helmholtz-Zentrum Dresden-Rossendorf (HZDR), D-01328 Dresden, Germany

Ionization potential depression (IPD) plays an important role in the modelling of high energy density (HED) systems. Constructed using the chemical model, IPD models aim to accurately treat the complex many-body effect of continuum lowering (CL) in a computationally efficient way. However, a number of experiments [1-4] have now demonstrated that commonly-used IPD models do not treat CL sufficient accurately in HED conditions. This has spurred further investigations into the nature of CL, and resulted in the development of new IPD models.

Benchmarking IPD models is challenging due to the difficulties in directly measuring CL in experiments, meaning there is limited data to compare against. Therefore, the direct measurements of CL in numerous materials by Ciricosta *et al.* [3] has proved invaluable. There, the IPD values for the different charge states of solid-density Mg and Al were extracted by observing the onset of Kα emission when changing the photon energy of the incident XFEL. However, a key conclusion from these IPD values is that the Mg and Al M-shells never rebind to the ions, even at high charge states. This conclusion was in part drawn from the lack of direct observation of Kβ emission from these materials, but it could not be discounted that they were simply too weak to observe.

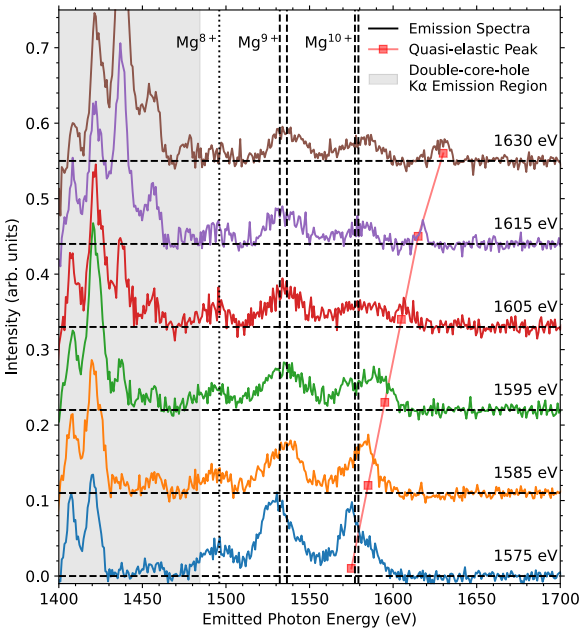

Fig. 1: Emission spectra [4] for different incident photon energies (labelled right) from solid-density Mg, showing Kβ emission from the Mg^{8+} to Mg^{10+} ions. Vertical lines indicate equivalent emission energies from isolated Mg ions from [6] (dashed) and [7] (dotted).

In this presentation, we discuss more recent experimental and theoretical investigations into the M-shell rebinding behaviour of highly-charged Mg. The key result is that Kβ emission has recently been directly observed in solid-density highly-ionized Mg [4] (see Fig. 1), indicating the M-shell can in fact rebind to the Mg ions. These findings are further supported by recent measurements of the Mg Heα lineshape [5], and finite-temperature density functional theory calculations [4]. Overall, these investigations strongly support that the IPD in the experiments lies somewhere between the Stewart-Pyatt and modified Ecker-Kröll models, and lower than inferred by [3]. Due to the similarities in the predicted ionization and localization behaviours of Mg and Al, we expect similar conclusions should be true for Al. Finally, we discuss the relevance of these results for the development of new IPD models.

References

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