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Collisional-radiative models (CRM) in transport modelling of edge and divertor fusion plasmas

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This paper focuses on the proper treatment of atomic and molecular (A&M) processes when modelling of the edge and divertor plasmas of tokamaks such as JET, ITER and DEMO as well as other fusion-relevant plasma devices like Magnum-PSI and PSI-2 linear simulators. The comprehensive modelling of such plasmas is critical for understanding (e.g. via spectroscopy) and controlling the plasma-surface interaction (PSI) issues critical for the realization of fusion as an energy source. The transport physics in such plasmas is difficult to decouple from the A&M side of the problem, thus a typical solution is to use a Monte-Carlo (MC) approach, such as that implemented in the EIRENE [1] and ERO codes. The former is iteratively coupled to transport codes to obtain a full plasma description, while the latter uses a given plasma background and considers wall material migration and other PSI issues. Both contain extensive and mature collisional-radiative models (CRMs) to provide input to the transport solvers.

It is worth noting that much can be learned even from the standalone CRMs [2] in a number of situations provided their results are interpreted keeping in mind the omitted transport side of the problem, e.g. by using extrapolations from the full-scale EIRENE simulations. Hence, it is best to have the same model used in both standalone and coupled operation mode. Results include synthetic diagnostics characterizing the wall erosion by plasma, branching ratios for various reaction groups useful for measurement and control of plasma detachment, etc. It was shown that resolving the vibrational states is essential for reaction branching simulation (e.g. resolving competing low temperature processes such as molecular assisted recombination (MAR) and dissociation (MAD), see **Fig.1**). The total dissociation in the divertor volume is affected, by ~40% for a typical JET case. Moreover, opacity effects (photon transport and Lyman absorption) [3] were demonstrated to add ~20% to the ionization rate. However, the tracking of so many vibrational, rotational or metastable states (critical for He, significant for W and multiple other elements) with acceptable statistical error sets unrealistic demands for the number of MC-tracked species.

In this context, to meet the CRM requirements stated above, we are currently developing a web-based A&M data preparation tool, Ploutos, part of a new universal kinetic module, ModCR, which provides a flexible treatment of internal states as test particles versus population variables and other features. We present ModCR and Ploutos use practices, results and limitations, and give perspectives for further development.

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References

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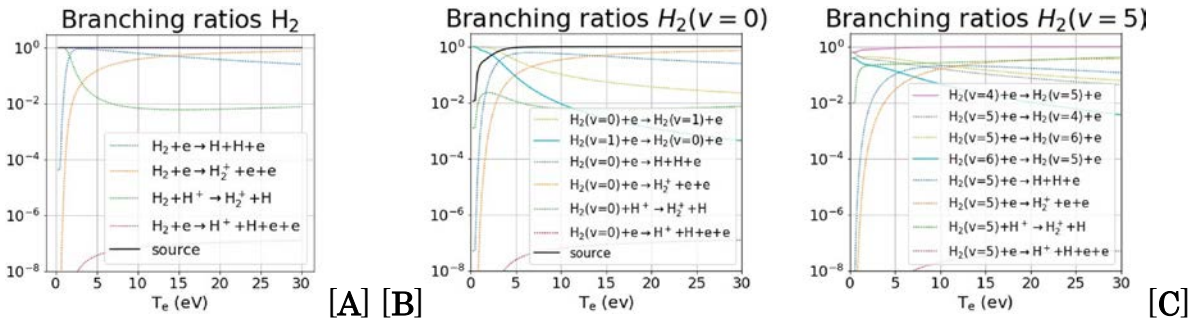

Fig. 1. *The branching rations for the H_2 molecule (constant source) reactions simulated by the standalone CRM with respect to temperature: [A] – no resolution by the vibrational state **v**; [B, C] – for H_2 in v=0 and v=5.*