Study of Molecular Hydrogen Data and Their Impact on CRMs and Exhaust Simulations for Detached Plasmas

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Divertor detachment is a key requirement for mitigating the target heat loads to develop fusion reactors in magnetic confinement devices. Plasma-molecular chemistry can play a key role in reducing the target particle loads, a key feature of plasma detachment, as well as power exhaust [1,2,3]. This arises from vibrationally excited molecules undergoing interactions with the plasma, forming molecular ions (D_2^+ and $D_2^- \rightarrow D^- + D$), which interact with the plasma – leading to power losses, particle losses, additional dissociation channels as well as hydrogenic emission, impacting diagnostic measurements. Such interactions have been shown to be relevant for reactors [4], particularly for tightly baffled alternative divertor designs that are employed in the STEP [5] and SPARC [6] reactor designs.

The work focuses on understanding plasma-molecular interactions in tokamak divertors, particularly regarding the impact of molecular hydrogen on plasma detachment. The project aims achieve this by first compiling experimental data from tokamak divertors for investigating plasma-molecular interactions, which can be used for benchmarking interpretive simulations. Secondly, molecular rates will be evaluated through collisional-radiative modelling and their impact on the divertor state will be investigated through plasma-edge modelling. Thirdly, the combination of the first and second point enables an assessment of the molecular hydrogen data requirements for interpreting tokamak divertor experiments and simulations.

The goal is to enhance the accuracy of exhaust simulations and reactor designs by improving the understanding and modelling of plasma-molecular interactions. This includes addressing the underestimation of molecular charge exchange in current simulations [1,4] and evaluating the impact of various rates on power exhaust physics, diagnostic analysis, and detachment control strategies.

References

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