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Analytical model for vibrational distribution function of hydrogen molecules in a cesium-free negative hydrogen ion source

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We study formation of the Vibrational Distribution Function (VDF) of hydrogen molecules in a cesium-free negative hydrogen ion sources at low pressure. The relative importance of the chemical processes in shaping the VDF at different pressures and absorption powers is quantified by performing a global sensitivity analysis (GSA) enabled by polynomial chaos expansions and evaluating the relative reaction rates contributing to the creation and loss of VDF. We find that the vibrational levels are excited by electron impact and deactivated in collisions with walls and this problem has a convenient analytical solution that can be used to obtain VDF and its dependence on external parameters [1]. The VDF is determined by excitation of vibrational levels by an external source and deactivation in collisions with the wall. Deactivation in wall collisions is little known process. However, we found that the VDF is weakly dependent on the functional form of the actual form of probability $\gamma_{\upsilon'\to\upsilon}$ for a vibrational number υ' to transfer into a lower level υ at the wall. Because for a given excitation source of vibrational states, the problem is linear the solution for VDF involves solving linear matrix equation. The matrix equation can be easily solved if we approximate probability, in the form: $\gamma_{\upsilon'\to\upsilon} = (1/\upsilon')\theta(\upsilon'-\upsilon)$. In this case, the steady-state solution for VDF(υ) simply involves a sum of source rates for levels above υ, with a factor of $1/(\upsilon+1)$. The analytical solution has been verified by comparing with a benchmarked and validated full model [2].

References

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