State-to-state Models for High Enthalpy Nozzle and Shock Tube Flows

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In the last years we have developed a comprehensive state-to-state (StS) kinetic model, coupling the master equations for internal distributions of heavy species with the Boltzmann equation for the free electrons and the radiative transfer equation (RTE) [1]. This model has been used to study the non-equilibrium H_2/He plasma formed during hypersonic entry in Jupiter atmosphere. The StS approach allows the most detailed level of description, fully considering the effect of non-equilibrium internal and electron distribution on chemical rate coefficients. In this work we apply the complete model to study the supersonic expansion of the plasma in an high enthalpy flow [2]. Depending on the total temperature in the reservoir the initial mixture can be composed, in addition to molecules and atoms, by free electrons and ionic species which can complicate the flow description. The ion-electron recombination creates distribution functions of electronic states of atoms far from Boltzmann ones inducing corresponding structures in the electron energy distribution function. It is shown that the radiation model has a strong impact on the evolution of the distributions and internal temperatures along the nozzle axis, resulting in completely different atomic state distributions and electron energy distribution functions in the optically thin and thick cases. This is compared with the situation met under hypersonic shock tube conditions, also taking into account the self-consistent coupling between radiation transport in the plasma slab and the rates of photoinduced processes.

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