Checking Salpeter's enhancement factor of nuclear reactions in asymmetric mixtures

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ABSTRACT

Since the seminal work of Salpeter [1], it is recognized that fusion reaction rates in stars are enhanced by the plasma environment, in every stage of their evolution: from main sequence stars to red giants, and eventually for the cooling of white dwarfs and the explosions of supernovae. This enhancement depends strongly on the Coulomb coupling and on the composition which varies from hydrogen-rich to degenerate carbon-oxygen cores. Even more asymmetric mixtures are found in Inertial Confinement Fusion and Warm Dense Matter experiments. Using orbital free molecular dynamics (OFMD) simulations we study mixtures of hydrogen-copper and hydrogen-silver as prototypes of a light-heavy plasma mixtures at 100 eV, various concentrations and constant pressure. We show that the ionic structure obtained by OFMD simulations is accurately reproduced by a multi-component hyper netted chain (MCHNC) calculation. In particular, the hydrogen-hydrogen correlation bump, which is a crowding effect caused by the collisions with the highly charged heavy component, is well reproduced. This adequacy of the MCHNC approach allows for a straightforward evaluation of the enhancement factor for nuclear reactions between light elements. This procedure is faster and more accurate than the Widom expansion used in previous work [2]. Being standalone and independent of simulations, the MCHNC approach allows to extend the range of thermodynamic conditions to very low concentrations in the heavy component (5% or less) and to very high temperatures (few keV). Enhancement factors for nuclear reactions rates are found close to Salpeter's strong coupling formulation below 2 keV and to the weak coupling formulation beyond 2 keV [3].

REFERENCES

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