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Nuclear Spin Dependent Chemistry of the Trihydrogen Cation in Diffuse Interstellar Clouds

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The trihydrogen cation, H_3^+ , long thought to be the species responsible for initiating ion-molecule chemistry in the interstellar medium, was first observed in interstellar clouds twenty years ago. Since its detection, this cation has been used to infer temperatures, densities, cloud sizes, and the local cosmic ray ionization rate. However, in diffuse molecular clouds the excitation temperature of its two nuclear spin modifications, ortho ($I = 3/2$) and para- H_3^+ ($I = 1/2$) is found to differ markedly from the cloud kinetic temperature inferred from the spin modifications of molecular hydrogen (H_2) in the same environment. A steady state analysis of the chemical kinetics of ortho and para- H_3^+ suggests that the interplay of thermalizing collisions with H_2 and nuclear spin dependent dissociative recombination with electrons may result in a nonthermal excitation temperature. Each of these processes is complex. Collisions between H_3^+ and H_2 must obey selection rules based on conservation of nuclear spin angular momentum, and the allowed spin conversion reactions, which proceed through the fluxional (H_5^+)* intermediate, each have different statistical weights and energetic requirements. Meanwhile, theoretical and experimental studies of H_3^+ electron recombination carried out over the past 40 years have yielded rates that span 4 orders of magnitude in range. We will present experimental measurements of the nuclear spin dependence of the reactions of H_3^+ with H_2 and with electrons, as well as astronomical observations of H_3^+ in diffuse molecular clouds and time-dependent chemical modeling of these environments. Astrochemical models incorporating the latest experimental data still do not satisfactorily explain the observed excitation temperature in diffuse molecular clouds, and point to the need for state-selective measurements of the H_3^+ electron recombination rate.