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Laboratory Studies of the H_2 Production Mechanism which led to the Formation of the First Stars

K. Miller[*], H. Bruhns[*], H. Kreckel[*], M. Lestinksy[*], X. Urbain[†], D. W. Savin[*]

[*] Columbia Astrophysics Laboratory, Columbia University, New York, NY 10027, USA
[†] Université de Catholique de Louvain, Belgium

Synopsis We have developed a novel apparatus to study associative detachment of H^- and H forming H_2. Beginning with an H^- beam, we use laser photodetachment to neutralize a fraction of the beam. This generates self-merged, anion-neutral beams. Laboratory beam energies are in the keV range. Because the beams run co-linear, center-of-mass energies from the meV to keV range are achievable. Our measurements will help to resolve the nearly order of magnitude scatter in previously published results. Resolving this issue will have major implications for understanding the early universe chemistry which led to the formation of the first stars and protogalaxies.

We have developed a novel merged beam apparatus to study anion-neutral reactions. The proof-of-principle measurement is the associative detachment (AD) reaction

$$H^- + H \rightarrow H_2^- \rightarrow H_2 + e^-. \quad (1)$$

Despite over 40 years of theoretical study, the various published results have yet to converge in either the magnitude or energy dependence for this most basic molecular formation process in negative ion chemistry. The one measurement for this system, a flowing afterglow study, has at least a factor of 2 uncertainty. A more detailed discussion of these previous studies is given in Glover et al. [1]

Uncertainties in reaction 1 have major implications for our understanding of the formation of the first stars and protogalaxies. The nearly order of magnitude uncertainty in the rate coefficient affect predictions of whether or not a given protogalactic halo can cool and condense before being gravitationally disrupted by a collision with another halo [1].

Our novel laboratory apparatus begins with an H^- beam produced using a duoplasmatron source and selected with a Wien filter. Typical beam energies used are $eU_{source} \sim 10$ keV. The extracted beam is bent around a 90° turn by a spherical deflector in order to prevent source-generated UV photons and neutrals from entering the interaction region of the apparatus and possibly altering the chemistry studied.

After the 90° bend the ions pass through a floating cell in which they are crossed with a 1.4 kW IR laser (975 nm) at an angle of 2.7°. Nearly 10% of the beam is neutralized by photodetachment to create self-merged anion-neutral beams. The floating cell itself is biased at a potential, U_{float}. Neutral H atoms leave the floating cell with laboratory energy of $e(U_{float} + U_{source})$. The remaining anions leave the floating cell and return to their initial energy eU_{source}. By selecting the potential on the floating cell we can set the center of mass energy E_{cm} between the ions and neutrals with an accuracy of a few meV.

After leaving the floating cell, the anions and neutrals interact for about a meter after which the anions are removed from the beam by a quadrupole deflector. The remaining H beam and any AD-generated H_2 then pass through a gas cell of He at a pressure of ~0.2 mTorr. Stripping collisions within the gas cell ionize a few percent of the AD-generated H_2. The cross section for this reaction is well known [2]. The resulting H_2^+ ions enter an analyzer where two sequential cylindrical deflectors direct the H_2^+ onto a channel electron multiplier.

Here we will report on the current status of the apparatus development and present preliminary results for reaction 1. To the best of our knowledge, this work represents the first use of merged, fast anion-neutral beams to study anion-neutral chemistry. With minor upgrades, we can use this apparatus to study AD reactions for a range of homo-nuclear systems. Carrying out such measurements would dramatically enhance our experimental knowledge of the AD processes.

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References

[1] Glover, S. C., et al., 2006, *Astrophys. J.*, **640**, 553.

[2] Barnett, C.F. 1990, *Atomic Data for Fusion: Vol. I*, Oak Ridge National Laboratory, ORNL-6086.

E-mail: kmiller@astro.columbia.edu
E-mail: savin@astro.columbia.edu