Development of a linear wave Stark velocity filter for studying cold ion-polar molecule reactions in interstellar clouds

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Synopsis We have developed a new type of a Stark velocity filter for widely changing the translational and rotational temperatures of polar molecules without changing the beam position. The performance evaluation has been done.

Cold ion-polar molecule (PM) reactions play important roles in the synthesis of interstellar molecules and the chemical evolution in interstellar clouds because the ion-dipole capture rates are particularly fast at low temperatures. In astrochemistry the time evolution of the chemical composition in interstellar molecular clouds is numerically calculated using reaction networks and databases, such as the UMIST database, for better understanding of the chemical evolution [1]. However, the experimental reaction-rate constants of ion-PM reactions at low temperatures are insufficient known owing to experimental difficulties, such as condensation and sublimation of polar gases at low temperatures.

In the above contexts, the reaction-rate constants of some cold ion-PM reactions have been measured in our laboratory using a new experimental technique, which combines sympathetic laser cooling in a linear Paul trap for generating cold molecular ions with a Stark velocity filter for producing cold PMs [2-5]. Unfortunately, the measurements were performed only at an restricted translational and rotational temperature range. Actually the translational temperatures of PMs were lower than 10 K, which is mainly limited by the radius of curvature of the Stark velocity filter [2]. The effective rotational temperature of the velocity-selected PMs was a constant because the temperature of the input polar gases was fixed to room temperature.

In this work, we have developed a new type of Stark velocity filter for changing the translational and rotational temperatures of PMs over the temperature range of molecular clouds (10-100 K) *without changing a beam position* [6]. Figure 1(a) shows the new structure of our Stark velocity filter. The translational temperature of guided PMs can be significantly changed by replacing the deflection section with a different radius of curvature R and a different deflection angle θ. On the other hand, a temperature variable gas cell attached to a cryocooler is installed as a source of polar molecules for generation of rotationally cooled PMs.

As shown in Fig.1 (b), we have performed time-of-flight measurements for velocity-selected ND_3 and CH_3CN, and determined the translational temperature range that could be varied. The number densities of the velocity selected PMs were determined experimentally, and the rotational temperatures were evaluated by comparing the experimental results with numerical simulations.

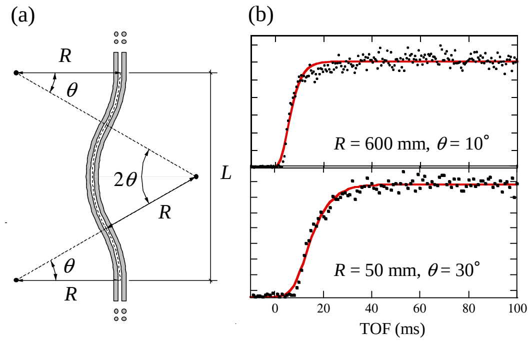

Figure 1 (a) Structure of a linear wave Stark velocity filter. (b) Time-of-flight signals of velocity-selected ND_3 obtained by the linear wave Stark velocity filter with different deflection sections. At t = 0, the guide voltage of the Stark velocity filter was turned on.

References

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