Selecting Slow Molecules

H. Kanamori, Y. Okuda, T. Sekiguchi, H. Tsuji and N. Toda
Department of Physics, Tokyo Institute of Technology

It is necessary to establish general methods to get cold molecules in the gas phase, which would play important role like the laser cooling method for cold atoms. Several ideas have been proposed and are developing to overcome or to use its advantage of complex internal structure of molecules. Most of them try to remove the energy from the molecules but there is an exceptional way to get cold molecules. A portion of molecules is present with slow velocity in the Maxwell-Boltzmann distribution. In the case of a light molecule, 1K of the translational energy corresponds to the velocity of 30m/s. The ratio of the velocity less than 30m/s is 10^{-5} in the total distribution. However the total number of molecules in a gaseous standard condition is 10^{19}/cc, so the number of molecules with the temperature less than 1K would be 10^{14}/cc. This is a quite large number compared with that cold atoms and molecules prepared by the other methods so far. If one can pick up those slow components effectively from a large number of the fast ones, it would be a powerful method. As such a slower filter, Stark effect of polar molecules is useful because space gradient of electrostatic field works as a trap potential to polar molecules. By using this way, a continuous source of translationally cold molecules was first demonstrated by Rempe's group[1]. Slow H_2CO molecules from an effusive CW nozzle source were selected by quadrupole Stark filter.

We intend to make a pulse source of slow molecules for a farther manipulation of cold molecules. We use a pulse nozzle in the effusive condition. The nozzle itself is cooled down by a liquid nitrogen trap. The vacuum chamber is separated into three sections for differential pumping. At the final stage of the stark guide, a fast ionization gauge detects the guided slow molecules. We chose the NH_3 molecule for the first sample.
In the case of NH_3, an electric field of 100kV/cm gives a Stark energy of $1cm^{-1}$ and this would become a trap potential barrier of the transversal direction of quadrupole axis. If the quadrupole guide is bent with a curvature of 3cm, molecules with the longitudinal velocity of more than 30m/s would escape from the trap potential due to centrifugal force. As a result the slow molecules are guided along the quadrupole. As the internal energy is not cold in the slow molecules, Stark effect of each rotational state with a hyperfine interaction is calculated, and the trajectory of the molecule in the stark field is simulated. Thus a system optimized for the NH_3 molecule has been constructed.

1) S. A. Rangwala, T. Jungen, T. Rieger, P. W. H. Pinkse, and G. Rempe., Phys. Rev. A **67**, 043406 (2003).