SPECTROSCOPY AND CHEMISTRY OF COLD MOLECULES

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Molecules at low temperatures are expected to behave quite differently from those at high temperatures because pronounced quantum effects emerge from thermal averages. Even at 10 K, a significant enhancement of reaction cross section is expected due to tunneling and resonance effects. Chemistry at this temperature is very important in order to understand chemical reactions in interstellar molecular clouds. At temperatures lower than 1 K, collisions and intermolecular interactions become qualitatively different from those at high temperatures because of the large thermal de Broglie wavelength of molecules. Collisions at these temperatures must be treated as the interference of molecular matter waves, but not as hard sphere collisions. A Bose-Einstein condensate is a significant state of matter as a result of coherent matter wave interaction. Especially, dense para-H_2 molecules are predicted to become a condensate even around 1 K. A convenient method to investigate molecules around 1 K is to dope molecules in cold matrices. Among various matrices, quantum hosts such as solid para-H_2 and superfluid He nano-droplets have been proven to be an excellent host for high-resolution spectroscopy. Rovibrational motion of molecules in these quantum hosts is well quantized on account of the weak interactions and the softness of quantum environment. The linewidths of infrared spectra of molecules in the quantum hosts are extremely narrow compared with those in other matrices. The sharp linewidths allow us to resolve fine spectral structures originated in subtle interactions between guest and host molecules. In this talk, I will describe how the splitting and lineshape of high-resolution spectra of molecules in quantum hosts give us new information on the static and dynamical interactions of molecules in quantum medium. The topics include dynamical response of superfluid environment upon rotational excitation, and possible superfluid phase of para-H_2 clusters. I will also describe our current efforts to make free cold molecules for the study of cold chemistry.