Millimeter-wave Spectroscopy of the $(He)_n$-HCN clusters

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Recent development of the infrared spectroscopy reveals that the superfluidity appears from n=9 for the $(He)_n$-OCS clusters.[1, 2] The superfluidity of the $(He)_n$-HCN clusters may appear from the n value smaller than 9 because the intermolecular interaction energy and the anisotropy of the potential between He and HCN are smaller than those between He and OCS.

We have observed the internal rotation and intermolecular stretching bands of He-HCN with millimeter-wave absorption spectroscopy combined with a pulsed supersonic jet expansion technique and determined the intermolecular potential energy surface.[3] We also have observed many weak lines around 100 GHz by using high stagnation pressure ($\sim$40 atm), which may be the lines of $(He)_2$-HCN and $(He)_3$-HCN. Some of these lines have nuclear quadrupole hyperfine structures. The analysis of the internal rotation fine structures observed by millimeter-wave spectroscopy will give us the precise in-formation of the energy levels and intermolecular interaction potential.

From the pattern of the spectrum, we tentatively assigned the spectrum around 104 GHz to $(He)_2$-HCN. The $(He)_2$-HCN seems to have a structure bound as He—H-C-N—He and the HCN part and He——He part are rotating almost freely. The Coliolis coupling of the HCN internal rotation and the end-over-end rotation of He-HCN-He is around 1/10 of that of He-HCN, since the center-of-mass of HCN is near to the center-of-mass in He-HCN-He. The potential energy surface of He-HCN-He was estimated by adding the empirical intermolecular potentials of He-HCN and He-He. The intermolecular potential of He-HCN-He along the minimum energy path is less anisotropic than that of He-HCN. The He-HCN-He has quite low frequency intermolecular bending vibration.

We are developing the low temperature supersonic jet nozzle for the efficient production of the He clusters and the millimeter-wave resonator to improve the sensitivity of the observation of the internal rotation transitions. The low temperature condition obtained by the low temperature jet nozzle is also important to reduce the intensities of the intermolecular bending hot band transitions, which will give us the definite assignments of the fundamental band transitions.

[1] J. Tang et al., Science **297**, 2030 (2002).
[2] A. R. W. McKellar, et al., Phys. Rev. Letters, **97**, 183401 (2006).
[3] K. Harada et al., J. Chem. Phys. **117**, 7041 (2002).