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

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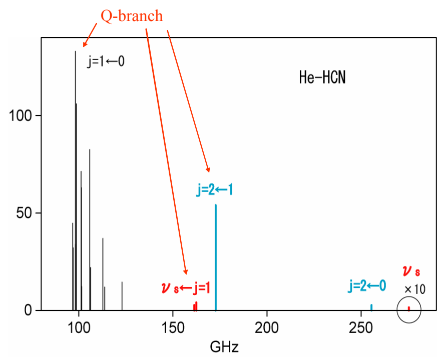
Recent development of the infrared spectroscopy reveals that the superfluidity appears from n=9 for the $(He)_n$-OCS clusters.[1] The superfluidity of the $(He)_n$-HCN clusters may appear from the n value smaller than 9 because the intermolecular interaction energy and the anisotropy of the potential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

In the present research project, we will observe the internal rotation bands of the $(He)_n$-HCN clusters by millimeter-wave spectroscopy. The analysis of the internal rotation fine structures observed by millimeter-wave spectroscopy will give us the precise information of the enegy levels and intermolecular interaction potential.

Fig.1. Observed spectrum of He-HCN.



We have observed the internal rotation and intermolecular stretching bands of He-HCN and determined the intermolecular potential energy surface.[2] Millimeter-wave absorption spectroscopy combined with a pulsed supersonic jet expansion technique has been applied to the observation. Figure 1 shows the observed spectrum. Transitions belonging to the j=1←0, j=2←1, j=2←0, ν_s, and ν_s←j=1 bands were observed in the frequency region of 95-280 GHz, where j is the quantum number of the rotational angular momentum of HCN and ν_s refers to the intermolecular stretching excited state. Most lines observed are Q-branches for the He internal rotation, which means that the 99.5 % of the He-HCN excited by a millimeter-wave radiation does not change the angular momentum of the He internal rotation and change the angular momentum of the HCN internal rotation or the vibrational energy of the intermolecular stretching vibration. When we have applied high stagnation pressure (～40 atm) to the supersonic jet nozzle, we have observed many weak lines around 100 GHz, which may be the lines of $(He)_n$-HCN. Some of these lines have nuclear quadrupole hyperfine structures. Since the spectrum is quite weak and complicated, we could not assign them.

The aim of the present project is to develop the new detection method using the millimeter-wave resonator to improve the sensitivity of the observation of the internal rotation transitions. Another aim of the present project is to develop the theoretical prediction method for the internal rotation transitions of He_2-HCN and He_3-HCN. The summation of the empirical 2-body interaction potential determined by the analysis of the observed internal rotation transitions will give us the good start point for the theoretical prediction.

[1] J. Tang *et al.*, Science **297**, 2030 (2002)
[2] K. Harada *et al.*, J. Chem. Phys. **117**, 7041 (2002)