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Infrared spectroscopy of acetylene fine particles formed in a pulsed supersonic jet

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Acetylene (C2H2) is an important species in various regions of interstellar space and planetary atmospheres. C2H2 molecule has been detected thus far in the carbon rich objects, and is expected to play an important role in the chemical processes of organic molecules. The presence of C2H2 has also been confirmed in the atmospheres of the outer planets Jupiter, Saturn, Neptune, and Saturn's satellite Titan. In particular, C2H2 clusters are likely to exist as van der Waals complexes or aerosols, respectively, in Titan and Neptune. Although crystalline C2H2 has not yet been found in interstellar ice, it can be a candidate for detection in the future. Solid C2H2 exists in two phases, namely an orthorhombic phase at low temperatures and a cubic phase at higher temperatures with the phase transition occurring at 133 K. In most previous spectroscopic studies, the infrared spectrum of solid C2H2 in the low temperature orthorhombic phase has been measured by depositing on the cold substrate window connected with a cryostat. For the cubic crystal phase, only one infrared spectrum has been reported by Dunder and Miller (1990).

In this study, a new step-scan Fourier transform infrared (FTIR) spectrometer combined with a pulsed nozzle system was used to record the infrared absorption spectra of C2H2 monomer, clusters and solid. In the experiments, C2H2 diluted in Ar was expanded into a vacuum chamber through the pulsed nozzle with 0.8 mm diameter orifice at a stagnation pressure of 0.35 MPa. The infrared spectrum was recorded by the Fourier transform infrared (FTIR) spectrometer equipped with step-scan mode. The spectral resolutions for high-resolution and low-resolution measurements were 0.25 and 4 cm^-1, respectively. The infrared spectra of C2H2 monomer were observed between 3270 and 3310 cm^-1, and the rotational temperature as low as 12 K was determined from the spectrum. A broad band was also observed between 3220 and 3260 cm^-1 with a dominant peak at 3233 cm^-1. This broad band could be reproduced by the sum of two Lorentzian components with the peak positions of 3233 and 3242 cm^-1, respectively. The broad bandwidth and the rotationally unresolved structure of the band with a dominant peak at 3233 cm^-1 indicate that this band is attributed to solid C2H2. The peak position and bandwidth were agreement with that of the spectrum of cubic C2H2 measured by Dunder and Miller. The 3242 cm^-1 band shifted by 8 cm^-1 higher and broader than that for cubic C2H2 is likely to be attributed to lager clusters or ultrafine particles of C2H2.

Infrared absorption spectrum of solid C2H2 was also measured on various experimental conditions. By using different concentrations and varying the stagnation pressure in the range of 150-450 kPa, it is possible to vary the rotational temperature of the molecules in the supersonic jet. Several different mixtures of acetylene in Ar are used; 5, 10, 15, 20, and 40%. As the concentration decreases, the absorbance for cubic C2H2 increases. As a result of the higher stagnation pressure, the production ratio of cubic C2H2 is higher. In all experimental conditions of this study, it found that the particles exist in the high temperature cubic phase of the solid C2H2.

It is expected that the infrared absorption spectrum obtained in this study serves as a key of identification of cubic acetylene in future observation.