Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS025-P06 Room:Convention Hall Time:May 23 10:30-13:00

UV-CPL irradiation experiment of lactic acid: photostability, racemization, and asymmetric decomposition

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Introduction: Since L-amino acid enantiomeric excesses (e.e. = 0.4 - 9.1%) were found in carbonaceous chondrites (Cronin and Pizzarello, 1997), the study on the origin of homochilarity in space has been developing. In particular, detection of circular polarized light (CPL) in the star forming regions (Bailey, 1998; Fukue, 2010) has provided an opportunity for a number of the UV-CPL irradiation of amino acids or its precursors to detect e.e. experimentally (e.g., Takano et al. 2007; Takahashi et al. 2009). However, the production mechanism of molecular homochilarity and a possibility of homochirality production of the other extraterrestrial organic molecules than amino acids have been infrequently investigated. Recently, e.e. of L-lactic acid (3 - 12%) from carbonaceous chondrites have been newly reported (Pizzarello, 2010). We have conducted the UV-CPL irradiation experiment of lactic acid in aqueous solution, as a starting study to understand the homochilarity of lactic acid in space.

Experimental: 0.02 mM DL lactic acid (D:L = 1:1) in aqueous solution, 0.01 mM L-lactic acid in aqueous solution and 0.01 mM D-lactic acid in aqueous solution were prepared. Four ml of in quartz cell was irradiated with UV-CPL. Left and right UV-CPL at 215nm from a free electron laser produced at BL5U, UVSOR. Power of irradiation was 10-200mWh. After irradiation, 100 micro L of the sample solution was analyzed by High Performance Liquid Chromatography (HPLC) with UV detector (254 nm). For the optical resolution of D- and L- lactic acids, ligand exchange chiral HPLC column (D-penicillamine ODS silica, SUMICHIRAL, OA-5000) was used. 1 mM copper sulfate aqueous solution was used for the mobile phase. Identification and quantification of compounds were made by comparison of peak retention times on HPLC chromatograms and peak areas, respectively, with those of standard compounds.

Results and discussion: For every sample, the concentrations of lactic acid exponentially decreased with increasing irradiation power, indicating the progress of photodecomposition of lactic acid. After 100 mW irradiation, the concentration of lactic acid decreased to less than 1% of the initial concentration. There was no difference in the concentration change between left and right CPL. Irradiation of D-lactic acid yielded L-lactic acid, and the ratio of D to L came close to 1:1 with increasing irradiation power. The opposite result was obtained by irradiation of L-lactic acid. There was no difference in the ratio change between left and right CPL. These results are probably reflected by deprotonation and racemization of a lactic acid molecule. A small e.e. was detected after irradiation of DL-lactic acid in this study. However, at this stage, it is difficult to determine whether the value is a true e.e. or analytical error. To be summarized, photodecomposition, racemization, and asymmetric decomposition of lactic acid occur simultaneously during UV-CPL irradization, which gives a final e.e., if any. If the obtained e.e. in this study is a true value, CPL would have likely played a role of inducing the initial small asymmetry of lactic acid, which can be consistent with the past studies about amino acids (e.g., Flores et al. 1977).

References:
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Keywords: homochilarity, circular polarized light, lactic acid, photostability, racemization, asymmetric decomposition