Measurements of nitric acid formation in humidified air by proton irradiation

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Gas-phase particle formation by the irradiation of ionizing particles (ionizing radiations) is an important process involving condensable chemical species, such as a water, nitric acid, and sulfuric acid, under conditions of atmospheric pressure and temperature. This phenomenon, the so-called "ion-induced nucleation," has attracted attention as one of the important processes leading to cloud particle formation in the atmosphere.[1,2] Sulfuric and nitric acids are thought to be important chemical species for the nucleation processes in the atmosphere. However, the detailed processes of such acid formations by the irradiation of ionizing particles have not been identified experimentally. Furthermore, large injection of ionizing particles into the atmosphere, such as solar proton events, causes an increase of the atmospheric nitric acid.[3] For understanding the influences of such injection events on the atmospheric environment, laboratory experiments on nitric acid formation by ionizing particle irradiation potentially can provide helpful information. Therefore, we investigated the formation processes of sulfuric and nitric acids by the irradiation of protons. As the first step, we performed experiments for nitric acid formation in humidified air by the irradiation of a proton beam.

The setup for the present experiment consists of a humidified sample-gas generator, an irradiation chamber, a monitor for the sample gas pressure, and a filter-pack holder used for collecting the nitric acid that forms in the sample gas. Wet air was generated by bubbling pure air in ultra-pure water. The sample gas was produced by mixing the wet air with pure dry air. The humidity of the sample gas was adjusted by controlling the flow rates of the wet and dry gases. The total flow rate of the sample gas was maintained at 2.5 SLM (Standard Liters per Minute) using mass flow controllers. The humidity of the sample gas was monitored using a dew-point meter. The sample gas was introduced into the irradiation chamber consisting of a borosilicate glass nipple tube with a length of 25 cm. The 6 MeV proton beam delivered from the 6 MV Pelletron accelerator at Tandem accelerator complex in University of Tsukuba was introduced into the irradiation chamber through a polyimide-film window. The proton beam penetrates along the glass tube, as well as the sample gas flow. After irradiation by protons, the sample gas was transported into the filter holder in which three kinds of filters were stacked along the gas flow to collect the gas-phase nitric acid and other chemical species in the irradiated gas (Filter-pack method[4]). A polyamide membrane filter was used for collecting the gas-phase nitric acid. The collected nitric acid on the polyamide filter was dissolved in 40 mL ultra- pure water. The amount of nitric anion, NO_3^-, in the solution was measured using ion chromatography analysis. The amount of nitric acid in the irradiated gas was estimated from those of NO_3^- ions in the solution under the assumption that the collection efficiency of the gas-phase nitric acid with the polyamide filter was 100%.

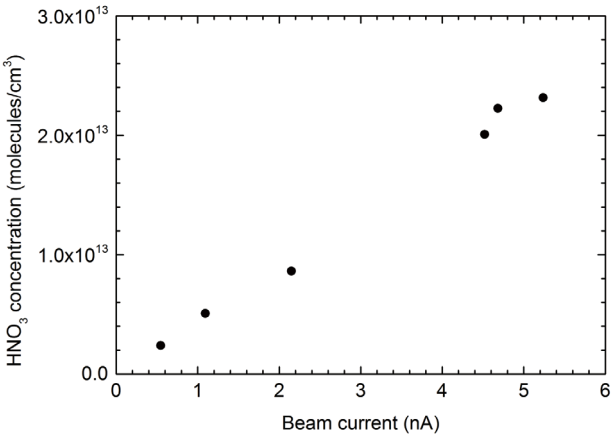

Fig. 1. Concentrations of gas-phase nitric acid in the proton-irradiated gas versus beam intensities (preliminary).

Figure 1 shows the preliminarily results for the concentrations of the gas-phase nitric acid produced in the proton-irradiated gas under the condition of 1 atm pressure, ∼42% relative humidity, and ∼296 K temperature; the concentration was estimated by dividing the amount of collected nitric acid by the total volume of gas passing through the filters. It is found that the production of nitric acid is almost proportional to the beam intensity. Certain factors, such as collection efficiency of the gas-phase nitric acid, are yet to be considered. Further analysis and consideration are now proceeding.

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