An Experiment for Understanding the Effect of Solar Cosmic Rays to the Upper Atmosphere

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1 Introduction

The nitrate concentration in polar ice cores correlates with the intensity of solar and/or galactic cosmic rays in Polar Regions. Zeller and Parker observed an 11-year variation of the nitrate abundance in polar ice cores[1]. Recently, Watanabe et al have found an 11-year variation of the nitrate concentration in an ice core from Antarctica, which, surprisingly, correlates positively with sunspot number[2]. Shea and Smart, based on Zeller's data, reported that several peaks of nitrate concentration in polar ice cores coincide in the time with well-known large solar flares[3].

The most well-known 11-year variation is solar activity. However it is not so clearly understood why the nitrate concentration in ice cores should correlate with solar activity, and what the corresponding mechanisms responsible for the correlation might be. Usually, biological processes produce most nitric oxides at stratospheric levels but these are at a minimum in the Polar Regions where the geomagnetic cut-off rigidity of cosmic rays is low and where cosmic ray production of nitric oxide is accordingly most efficient. We have investigated this subject from the view point that the 11-year variation of the nitrate abundance in the polar regions is produced by cosmic rays. To resolve this question, we need an answer on the production rate of odd nitrogen by cosmic rays experimentally, irradiating the accelerator beam on target gases.

2 Overview and result of the experiment

The first experiment was performed during July 4∼8th, 2000 at the ES course of the East Experimental Hall. Next, part of the experimental equipment was improved based on the first result, and a second experiment was carried out during November 20∼22th, 2000. The energy of the proton beam from the Ring Cyclotron was 392 MeV. The intensity of the beam was set in between 1nA and 10nA.

Five targets (air, nitrogen, oxygen, argon, vacuum) in a gas cell have been irradiated for about 1∼2 hours and the odd nitrogen produced by the beam has been measured using a Fourier Transform Infrared Spectrometer (FTIR).

Table 1 shows the molecules produced by the beam in each gas. It has been confirmed that odd nitrogen (NO_2, HNO_3) was produced only in the case when air was used as the target. Figure 1 shows the absorption spectrum of the molecules produced as measured by the FTIR; it can be seen that odd nitrogen was generated. This happens because molecule containing nitrogen are dissociated by the proton beam yielding nitrogen atoms, and these nitrogen atoms react with oxygen or ozone, making nitrogen dioxide by the reactions ($N+O_2 \rightarrow NO+O$; $NO+O_2 \rightarrow NO_2+O$). Because water vapour was mixed in the gas cell at the time of introduction, nitric acid should be generated (NO_2+OH → HNO_3). Moreover, nitric acid is adsorbed easily to a wall and nitrogen dioxide is also adsorbed to a wall to which water vapour was attached. From the data on the absorption spectrum of the gas, we have calculated the rate of production of odd nitrogen and other molecules by the proton beam. Figure 2 shows the result in the case when air at 1.1 atm was used as the target. We have estimated the production rate of odd nitrogen at the early stage of beam irradiation. The (preliminary) production rate is estimated to be 0.3 [NO_2 molecules/ionization], which is about one-fifth the theoretical values from various model calculations; 1.3[4], 2∼2.5[5], 1.3∼1.6[6], 1.5[7] [NO molecules/ionization]. This might be the result of the contamination of water vapour at the time of sealing the target gas. But we also note the possibility that the production rate of odd nitrogen might really be less than the theoretical value. We must repeat the experiment to get a conclusive value, removing the influence of water vapour.

	NO_2	HNO_3	N_2O	O_3	CO	CO_2
Air (0.5, 1.1, 2.0 atm)	○	○	○	○	○	○
N_2 (0.5, 1.1, 2.0 atm)	×	×	○	×	○	○
O_2 (0.23 atm)	×	×	×	○	○	○
Ar (1.1 atm)	×	×	×	×	○	○
Vacuum	×	×	×	×	△	△

(○:produced, ×:not, △:few)

Table 1: Production of molecules by the proton beam on five targets.

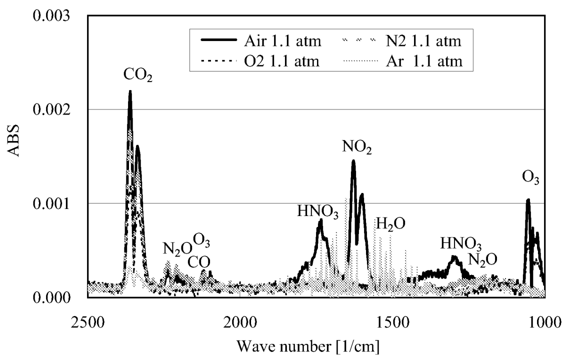

Figure 1: Absorption spectrum of odd nitrogen and other molecules produced by the beam.

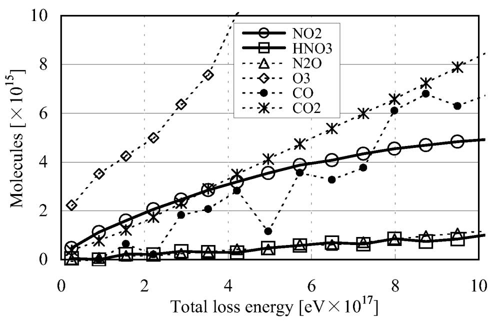

Figure 2: The production rate of odd nitrogen and other molecules by the beam in air of 1.1 atm.

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