1. Introduction

In 1990, the ROSAT satellite was launched and measured the soft x-ray background over the all sky. During the observation, it was discovered that the intensity of the soft x-ray background varies with short time within a few days in space where x-ray sources do not exist [1,2]. In 1996, the ROSAT satellite observed the soft x-ray emissions from the Hyakutake comet when it approached the earth [3]. After that, the x-ray emissions from various comets were observed and it was concluded that a part of the emissions is caused by the de-excitations in charge exchange processes between highly charged ions (HCl) in solar wind and cometary neutrals [4]. Since then it has been recognized that the long-term enhancements of the soft x-ray background stem from the solar wind charge-exchange (SWCX) with neutrals within the heliosphere as well as cometary neutrals [5-7]. In order to quantitatively analyze the high-resolution x-ray spectra observed with the satellites in detail, the cross sections in SWCX processes, in particular x-ray emission cross sections, are needed. However, there are no sufficient cross section data so far.

In these contexts, some x-ray emission cross sections in the SWCX processes have been measured for the electric dipole allowed x-ray transitions [8,9]. However, the main emissions in SWCX are known to be the forbidden and inter-combination transitions in O$^{6+}$ (1s2s/1s2p – 1s2 transitions) [7], which have not been measured yet in a laboratory. Since the ion beam has a velocity of 200 - 900 km/s in order to reproduce the solar wind, it is impossible to observe the transitions with long lifetimes over microseconds by beam-based experiments. Nonetheless, we have a chance to observe the forbidden transitions by trapping the metastable HCl ions after the charge-exchange reactions of O$^{5+}$ (1s) + He → O$^{6+}$ (1snl) + He$^+$.

In this work, we report on the development of a Kingdon ion-trap system for trapping high energy HCl beams produced by an electron-cyclotron resonance ion source (ECRIS). As a performance test of the instrument, we measured trapping lifetimes of Ar$^{5+}$ (q = 5, 6) under a constant number density of H$_2$. Some experimental problems and their solutions are discussed. Then, the charge-transfer cross sections of the Ar$^{5+}$ - H$_2$ collision systems were measured at binary collision energies of a few eV [10]. The results are compared to previous data and the values estimated by some scaling formula. Finally, we report on the status of the observation of the forbidden x-ray transitions from the metastable O$^{6+}$ (1snl).

2. Experimental Setup

In this abstract, I describe the setup of trapping lifetime experiment. The highly charged ion beams were produced by ECRIS at an acceleration voltage of 6.0 or 8.0 kV. We selected the ions with a desired charge-state by an analyzing magnet. Then the ions were injected into a Kingdon ion trap for trapping experiments. The ion beam current was measured with a Faraday cup installed at the most downstream of the beam line before applying high voltage into the trap electrodes.

Figure 1 shows a schematic drawing of the Kingdon ion trap. It consists of a central wire electrode, a cylinder electrode and two end-cap electrodes. After pre-determined storage time, the trapped ions were ejected and a part of the ejected...
ions are detected by a micro channel plate (MCP). The output pulse signals from the MCP are counted by a fast multichannel scaler. In the earlier study using the Kingdon ion trap, D. A. Church et al. reported that no product ions with lower charge state were stored after the charge-exchange collisions between Ar\(^{9+}\) and Ar [11]. However, our study showed that the ions produced by the charge-exchange collisions between Ar\(^{9+}\) and H\(_2\) were still trapped. Thus, we introduced the TOF measurement system in order to determine the trapping lifetime of HCIs. The data acquisitions were repeated 10\(^7\) - 10\(^8\) cycles depending on the ion beam current and storage time.

3. Results and Discussion

Figure.2 shows the decay of trapped Ar\(^{9+}\) (q = 5, 6) ions as a function of the storage time in H\(_2\) gas at a pressure of 1.24 \times 10\(^{-5}\) Pa. The decay rates of Ar\(^{5+}\) and Ar\(^{6+}\) were determined be 28(6) s\(^{-1}\), 67(6) s\(^{-1}\), respectively. In order to determine the charge-exchange cross sections from the decay rates, we need to know the average velocities of Ar\(^{9+}\) ions. For this purpose, we have performed extensive numerical simulations of ion trajectories trapped in the realistic Kingdon trap using the commercial software (SIMION8.0) and the average velocities of Ar\(^{5+}\) and Ar\(^{6+}\) were determined to be 1.8(0.3) \times 10\(^4\) m/s and 2.0(0.4) \times 10\(^4\) m/s, respectively. On the other hand, the number density of H\(_2\) was determined by the ionization pressure gauge. Finally, the charge-exchange cross sections for the Ar\(^{q+}\)-H\(_2\) and Ar\(^{q+}\)-H\(_2\) systems were determined to be 5.2(2.6) \times 10\(^{-15}\) cm\(^2\) and 1.1(0.5) \times 10\(^{-14}\) cm\(^2\), respectively. Note that the cross section of the Ar\(^{5+}\)-H\(_2\) system at the low energy was determined for the first time. These cross section data are consistent with the values estimated by the scaling formula and previous experimental data [12,13].

As a first step of the x-ray observation from the metastable O\(^{6+}\), we started the trapping experiment. Figure.3 shows a decay curve of the trapped O\(^{6+}\) ions as a function of the storage time in H\(_2\) gas at the pressure of 4.4 \times 10\(^{-7}\) Pa. The trapping lifetime of O\(^{6+}\) is determined to be 280(15) ms. Since the lifetime of the forbidden transition in O\(^{6+}\) (1s22s - 1s\(^2\) transition) is approximately 1 ms [14], the trapping lifetime is long enough to measure the forbidden transition.

The details of the discussions and the progress of the x-ray observation will be presented at the oral presentation and the master thesis.

References