Radiative lifetime of metastable Xe^{3+} measured using an electrostatic ion beam trap

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Synopsis We have measured the radiative lifetime of the $^2P_{3/2}$ metastable level in Xe^{3+} using an electrostatic ion beam trap. The lifetime was obtained by measuring the number of photons emitted during the $^2P_{3/2}\rightarrow{}^2D_{3/2}$ transition of Xe^{3+} as a function of the storage time. The lifetime is compared with previously reported theoretical and experimental values.

Measurements of radiative lifetimes for forbidden transitions of ions provide information that would be useful not only for improving the atomic and molecular structure models but also for applications such as the diagnostics of density and temperature in astrophysical and laboratory plasmas. The radiative lifetime of the $^2P_{1/2,3/2}$ metastable levels in the ground-state configuration ($5s^25p^3$) of Xe^{3+} has been studied experimentally and theoretically by several research groups. The experimental lifetime of the $^2P_{1/2}$ state (15.6 ± 0.9 ms [1]) was in good agreement with theoretical values (15.8 ms [1] and 16.4 ms [2]). On the other hand, the experimental lifetime of the $^2P_{3/2}$ state (5.3 ± 0.5 ms [1]) was smaller than the theoretical values (6.6 ms [1] and 6.8 ms [2]) even considering the experimental error. In this work, we measured the radiative lifetime of the $^2P_{3/2}$ metastable state of Xe^{3+} using an electrostatic ion trap of the ion-beam storage type [3, 4]. The trap was placed away from the ion source, which enabled us to prevent the inflow of the ion-source gas into the trap. This minimized the influence of ion-beam losses in the trap due to collisions with residual gases.

Figure 1 shows the experimental arrangement. A Xe^{3+} beam of 3.6 keV was produced using an electron impact ion source. The beam was chopped using an electrostatic chopper and was mass analyzed in a 45° deflecting magnet. The ion bunch was then injected into the trap, and was multiply reflected between the entrance and exit-side electrodes along the trap axis, resulting in the storage of the ion-beam in the trap. The 447 nm photons emitted during the $^2P_{3/2}\rightarrow{}^2D_{3/2}$ transition were measured with an optical system, which is composed of a view port, a bandpass filter (450 ± 12.5 nm), and a photomultiplier tube (PMT) as shown in Fig. 1. The count rate of photons as a function of time was recorded using a multichannel scaler (MCS). Since the count rate of the photons at a given time t is proportional to the number of Xe^{3+} ions in the $^2P_{3/2}$ state at the time t, we can obtain the lifetime of the $^2P_{3/2}$ state from the time spectrum of the photons. The trap was maintained at a pressure of about 1×10^{-7} Pa during measurements.

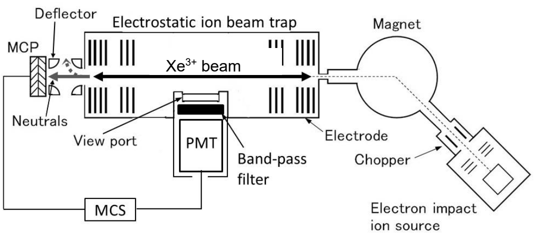

Figure 1. Experimental arrangement

We obtained a lifetime of 6.0 ± 0.7 ms from the time spectrum. However, this value is an apparent lifetime. Since the number of stored Xe^{3+} ions decreases with the trapping time due to electron capture or elastic collision with residual gases, the obtained value has to be corrected for the ion-storage lifetime. For that reason, the number of the stored Xe^{3+} ions as a function of time was monitored through the measurements of Xe^{2+} ions escaping from the trap, which were produced by single electron capture from residual gases in the trap. The preliminary result, corrected for the ion-storage lifetime, is 7.2 ± 0.9 ms. This value is in agreement with the previous theoretical values within the experimental error.

References

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