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Radiative lifetime of the metastable $^1S_0$ level in Kr^{2+} measured using an electrostatic ion trap

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Synopsis We have measured the radiative lifetime of the $^1S_0$ metastable level in Kr^{2+} using an electrostatic ion trap. The obtained lifetime was 17.4 ± 0.4 ms. Comparing with the previous results, our value is consistent with the theoretical predictions, but inconsistent with the experimental results even considering their errors.

The radiative lifetime of the $^1S_0$ metastable level in Kr^{2+} has been studied experimentally and theoretically by several groups [1]. The theoretical values reported by two groups (17.2 ms and 17.3 ms) were in good agreement with each other. On the other hand, the experimental values reported by two other groups (13.1 ± 0.6 ms and 14.8 ± 0.8 ms) were mutually inconsistent, and were smaller than the theoretical values. In this work, we measured the radiative lifetime of the $^1S_0$ metastable state of Kr^{2+} using an electrostatic ion trap of the ion-beam storage type [2, 3]. The trap was placed away from the ion source, and two differential evacuation systems were mounted between them, 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 Kr^{2+} beam of 2.4 keV was produced using an electron impact ion source. The beam was pulsed using an electrostatic chopper and was momentum analyzed in a 45° deflecting magnet. The beam pulse was then injected into the trap, and was multiply reflected between the entrance and exit-side electrodes, resulting in the storage of the ion-beam in the trap. The 350 nm photons emitted during the $^1S_0 \rightarrow {}^3P_1$ transition were measured with an optical system, which is composed of a view port, lenses, a bandpass filter (349 ± 5 nm), and a photomultiplier tube (PMT) as shown in figure 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 Kr^{2+} ions in the $^1S_0$ state at the time t, we can obtain the lifetime of the $^1S_0$ state from the time spectrum recorded using the MCS. The trap was maintained at a pressure of 5×10^{-8} Pa during measurements.

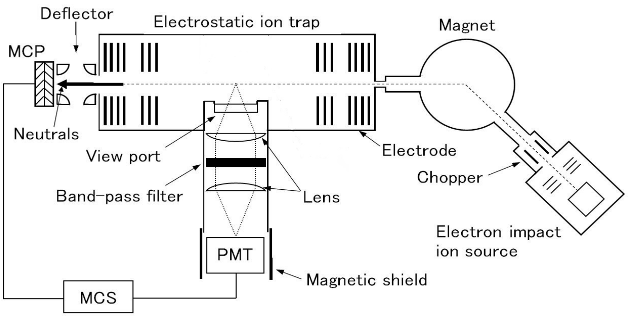

Figure 1. Experimental arrangement

The number of stored Kr^{2+} ions decreases with the trapping time due to electron capture or elastic collision with residual gases. Since the lifetime obtained from the photon time spectrum is composed of the radiative lifetime and the ion-storage lifetime, the accurate storage lifetime is necessary for the determination of the radiative lifetime. For that reason, the number of the stored Kr^{2+} ions as a function of time was monitored through the measurements of neutral Kr produced by double electron capture from residual gases in the trap.

To improve precision, three runs were done. About 100,000 beam pulses were injected into the trap per one run. The results yielded in the three runs agreed with each other within their errors. The lifetime of the $^1S_0$ metastable state of Kr^{2+} was determined to be 17.4 ± 0.4 ms from a weighted average of these results. Our value is in fair agreement with the previous theoretical values.

References

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