Complete ground state transition rates for the helium 2^3P manifold

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Experimental tests of Quantum Electrodynamics (QED) have focused on the precision measurement of key atomic parameters. These include atomic energy level intervals and transition rates, both of which require a complete relativistic treatment of the atom-light field Hamiltonian. High resolution experimental studies of the 2^3P fine structure intervals in helium have shown that differences of several standard deviations exist between experiment and the most recent QED theory.

Until the present work, there has been no comparable study of the transition rates from the 2^3P manifold to the ground state for He. As the fine structure interval studies show, it is important to perform a complete study over the entire manifold in order to test QED predictions. Further, this work completes the series of rare-gas 2^3P_2 lifetimes for Ne, Ar, Kr and Xe.

We present here the final in a series of three separate experiments aimed at determining the transition rates from the metastable helium 2^3S_1 state (He*) and from the 2^3P manifold to the ground state. Each measurement requires a different experimental technique that is optimised to account for the vastly differing transition rates (covering six orders of magnitude) and to benchmark the measured values against a known reference.

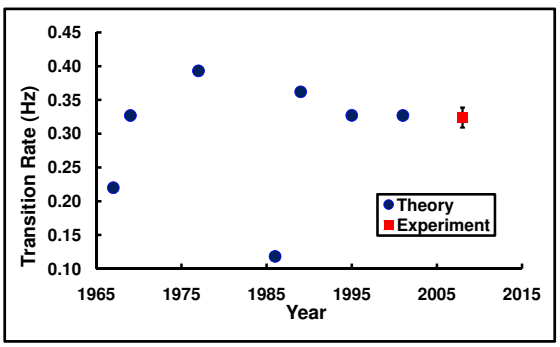

Fig. 1:)(a) Historical progress of theoretical predictions (references shown) for the $2^3P_2 \rightarrow 1^1S_0$ decay rate, along with our experimental determination and associated uncertainty. Estimated uncertainties for the theoretical results are smaller than the data points.

In these latest experiments we measure the rate of photon emission from the 2^3P_2 and 2^3P_0 states to the 1^1S_0 ground state relative to the emission rate from the $2^3P_1 \rightarrow 1^1S_0$ transition, which we have determined previously for the first time. The value for the $2^3P_2 \rightarrow 1^1S_0$ transition is 0.324 $\pm$ 0.016 s^{-1}. An upper bound of $\sim$0.01 s^{-1} is placed on the emission rate for the $2^3P_0 \rightarrow 1^1S_0$ transition, which is predicted to be strictly forbidden. Together with our previous measurement of the $2^3P_1 \rightarrow 1^1S_0$ transition rate [1], this work completes the first measurement of the decay rates from the helium 2^3P manifold to the ground state. Along with the measurement of the He* state lifetime [2], we have now determined the decay rates to the ground state for the first four excited triplet states of helium.

All of our experimental measurements are in excellent agreement ($<1\%$) with the most recent QED theoretical predictions [3], providing support for the accuracy of the 2^3P_1 decay rate (4.4$\%$) used to calibrate the other transitions.

References

[1] R. G. Dall, K. G. H. Baldwin, L. J. Byron, and A. G. Truscott, Phys. Rev. Lett. **100**, 023001 (2008).
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[3] G. Lach and K. Pachucki, Phys. Rev. A **64**, 042510 (2001).