Absolute Absorption Measurements of the Cs Line Strengths $6s\,^2S_{1/2}$—$7p\,^2P_J$ $(J = 1/2, 3/2)$

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We are studying the low-lying electronic states of atomic cesium because of their importance to the interpretation of atomic parity nonconservation measurements. Precision measurements of these line strengths test the behavior of theoretical atomic structure calculations especially at large radii. In cesium, the ratios of the line strengths

$$|\langle np\,^2P_{\frac{3}{2}}||r||6s\,^2S_{\frac{1}{2}}\rangle|^2/|\langle np\,^2P_{\frac{1}{2}}||r||6s\,^2S_{\frac{1}{2}}\rangle|^2 \tag{1}$$

are anomalously large for $n > 6$ due to relativistic effects in this heavy many electron system. Here we report on the progress of our measurements of these and other transition strengths in atomic cesium.

Precise measurements of transition amplitudes between low lying states in neutral cesium provide important tests of *ab initio* wave functions [1, 2] that are used in the interpretation of parity nonconservation experiments [3]. We have constructed a vapor cell absorption spectrometer for high-precision transition strength measurements. While accurate lifetime measurements can provide complementary information, only a few states decay without branching such that individual transition amplitudes can be determined to high precision. As an alternative test of wave functions, our absorption spectrometer [4] can provide measurements of relative transition amplitudes with uncertainties of less than $\pm 5 \times 10^{-4}$. Using known transition amplitudes [5] as a means for density calibration, we can also measure absolute transition amplitudes with our apparatus to uncertainties of order $\pm 3 \times 10^{-3}$ (presently limited by the uncertainty in our lifetime measurements of the calibrating transition amplitude).

The transitions of immediate interest here are the $6s\,^2S_{1/2}$—$np\,^2P_J$ $(J = 1/2, 3/2)$ absorption lines of atomic cesium. The fine structure energy splittings of these states are well known experimentally and have been studied through relativistic many-body perturbation theory (MBPT) [1]. The largest part of fine structure energy splitting is familiar to us in lowest order as the magnetic/relativistic single-particle effect called the spin-own-obit interaction. In the Pauli approximation for multi-electron atoms, the magnetic two body effects referred to as the spin-other-orbit, orbit-orbit, and spin-spin interactions are included as perturbations. Other relativistic effects, the single particle mass correction and single and two-particle Darwin terms, can be included as perturbations. These produce a shift, and do not contribute to the fine structure splitting.

For heavy atoms such as cesium a more sophisticated approach is required. Starting from the Dirac-Coulomb Hamiltonian using the relativistic unrestricted Hartree-Fock procedure in MBPT, all relativistic single particle effects are automatically included to all orders. The Breit Hamiltonian is usually added as a perturbation to include the magnetic two body effects to lowest order. All of these effects not only contribute to the fine structure energy, but can also have an impact on the atomic wave functions. The impact of the spin-own-orbit interaction on atomic wave functions was first recognized by Fermi [6] in his explanation of anomalies in the line-strength ratios of the principal spectral series of alkali atoms. Fermi showed that the off diagonal spin orbit interaction could produce large corrections to the wave functions.

Assuming a spherically symmetric atomic potential in the non-relativistic limit, one expects the principal series of the alkalis to yield a line strength ratio of 2:1 solely from angular momentum considerations. For most alkalis, the experimental line strength ratio for the lowest lying doublet transitions is very close to 2, however for the second and third doublets the ratio becomes large especially for heavy alkalis.

Our first ratio measurements in Cs [4] determine the ratio

$$|\langle 6p\,^2P_{\frac{3}{2}}||r||6s\,^2S_{\frac{1}{2}}\rangle|^2/|\langle 6p\,^2P_{\frac{1}{2}}||r||6s\,^2S_{\frac{1}{2}}\rangle|^2 = 1.9809(9) \qquad (2)$$

which is in excellent agreement with the all-orders approach of Blundell *et al.* For the case of $6s\,^2S_{1/2}$—$7p\,^2P_J$ $(J = 1/2, 3/2)$, the line strength ratio becomes much larger than 2 because deviations from a spherical potential and relativistic effects have a much larger effect on the $7p$ wave function.

In calculations of binding energies using the relativistic Dirac-Coulomb approach [7], core polarizations are included automatically. However comparisons with experimental energies show that correlations must also be included in the calculation in order to provide accurate fine structure splittings [8]. Thus we expect that a precise measurement of the fine structure line strengths might reveal the impact of correlations on the theoretical determination of atomic wave functions and matrix elements.

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