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Spin-forbidden Helium I transition rates

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Synopsis We have calculated spin-forbidden transition rates in neutral helium using the spin-orbit and spin-other-orbit Breit-Pauli operators.

We have begun a project to calculate the electric dipole (E1) spin-forbidden transitions in neutral helium and He-like ions. In the Breit-Pauli approximation these extremely weak transitions arise from the perturbation of the initial and final wave functions by the relativistic spin-orbit (SO) and spin-other-orbit (SOO) operators. Measurement of some of these transitions is now possible [1] so the numerical work is timely.

Our calculations involve several important features: (1) extremely accurate nonrelativistic wave functions for infinite nuclear mass in Hylleraas coordinates, (2) a sequence of pseudostates to represent all the intermediate states including the continuum in the sums, (3) perturbation of the $^1S_0$ and $^3S_1$ levels by the pseudostates corresponding to the doubly excited $npn'p\ ^3P_0^e$ and $npn'p\ ^1P_1^e$ respectively, (4) spin-changing matrix elements with the SO and SOO Breit operators acting between the pseudostates and the initial and final states, and (5) the use of both the length and velocity dipole interaction operators as a check on the accuracy of the results.

Table 1 lists some examples. There $\Delta\varepsilon$ is the energy difference in atomic units, λ is the wavelength of the transition, M_L is the length matrix element, M_V is the velocity element plus the relativistic corrections to the transition operator as described by Drake [2], f is the absorption oscillator strength and A the transition rate. Further details are available in recent papers by Morton, Moffat and Drake [3] and Morton and Drake[4].

A future step will add the finite-mass corrections to the Breit operators for use with wave functions already available with the mass-polarization included.

References

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Table 1. Matrix elements M, and f- and A-values for spin-forbidden transitions.

	$2\ ^1S_0 - 2\ ^3P_1$	$1\ ^1S_0 - 3\ ^3P_1$	$2\ ^3S_1 - 3\ ^1P_1$
$\Delta\varepsilon_\infty$ theory	0.012 809 855 271	0.845 643 292 8	0.120 083 016 1
λ(nm) vacuum	3 556.90	53.8801	379.432
M_L	$1.338\,711 \times 10^{-3}$	$1.013\,20 \times 10^{-4}$	$1.211\,766 \times 10^{-4}$
$M_V/\Delta\varepsilon_\infty$	$1.338\,711 \times 10^{-3}$	$1.013\,22 \times 10^{-4}$	$1.211\,766 \times 10^{-4}$
f	$1.530\,5 \times 10^{-8}$	$5.787\,6 \times 10^{-9}$	$3.918\,4 \times 10^{-10}$
$A(s^{-1})$	$2.689\,7 \times 10^{-2}$	44.326	0.181 54

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